Methodology to Estimate Pollutant Load Reductions

Final Report Appendices

Prepared for:
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Contract DACW05-02-D-0001-0007-01
April 21, 2006

Appendices

Appendix A – Simple Guidance for Pollutant Load Reduction Estimator for Storm Water
Appendix B – Examples and Discussion of Output Pollutant Load Estimator for Storm Water
Appendix C – Lake Tahoe Basin Interviews
Appendix D – Researcher Interview Summaries
Appendix E – Literature Search Database
Appendix F – Comments and Responses

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Appendix A – Simple Guidance for PLRE-STS

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Table of Contents

List of Tables

List of Figures

A.1 Introduction

The following appendix provides simple guidance regarding the file structure and general linkage of the worksheets contained within the Pollutant Load Reduction Estimator – Spreadsheet for Tahoe Storm Water (PLRE-STS), developed to estimate load reductions from storm water quality improvement projects. This appendix is **not** a detailed User's Guide and does not provide guidance on selecting appropriate input parameters, evaluating default data, or interpreting output data. In its current form, the PLRE-STS is not intended for distribution or use by Lake Tahoe implementers and stakeholders. Additional testing, refinement, calibration, and validation are still needed to minimize potential inaccuracies and errors, and to ensure the PLRE-STS is robust for application to a wide-range of scenarios. The reader is referred to Section 9 of this report to review the recommended refinements to the PLRE-STS.

The document is organized in the following sections:

1. Installing and running the PLRE-STS.
2. Descriptions of input/output worksheets within the PLRE-STS
3. Input data descriptions

A.2 Installing and Running the PLRE-STS

To install the PLRE-STS, extract the files from **PLRE-STS.zip.** The default location for extraction is the root C: drive - **C:\PLRE-STS**. Figure A.1 illustrates the directory structure when the files are extracted to the default location. The folders **RainInt, RuIn, RuInt, StIn, StOut, SWMMExes, TempInt,** and **Templates** contain the preprocessed MM5 data and the files necessary to run the SWMM hydrology engine. The files in these folders should not be modified by the user and are not discussed in this document. The folder **Examples** contains example simulations as described in detail in Appendix B.

The PLRE-STS is an Excel spreadsheet, which can be saved and copied to produce multiple storm water load simulation runs. Multiple copies of the Excel spreadsheet can be made and will run separately from each other. To create an additional file, the user simply saves a current version of the PLRE-STS with a new name. When the PLRE-STS is run, the SWMM engine will use the files in the directory structure (Figure A.1) as input and intermediate storage, but will write all output data to the PLRE-STS worksheets. This structure allows for transmittal and viewing of selected input data and output in the well-known Excel format. For example, a user could email a simulation to an outside party for review, and the outside party would not need the SWMM engine or directory files (Figure A.1) to review output, input data, and general assumptions made for the simulation.

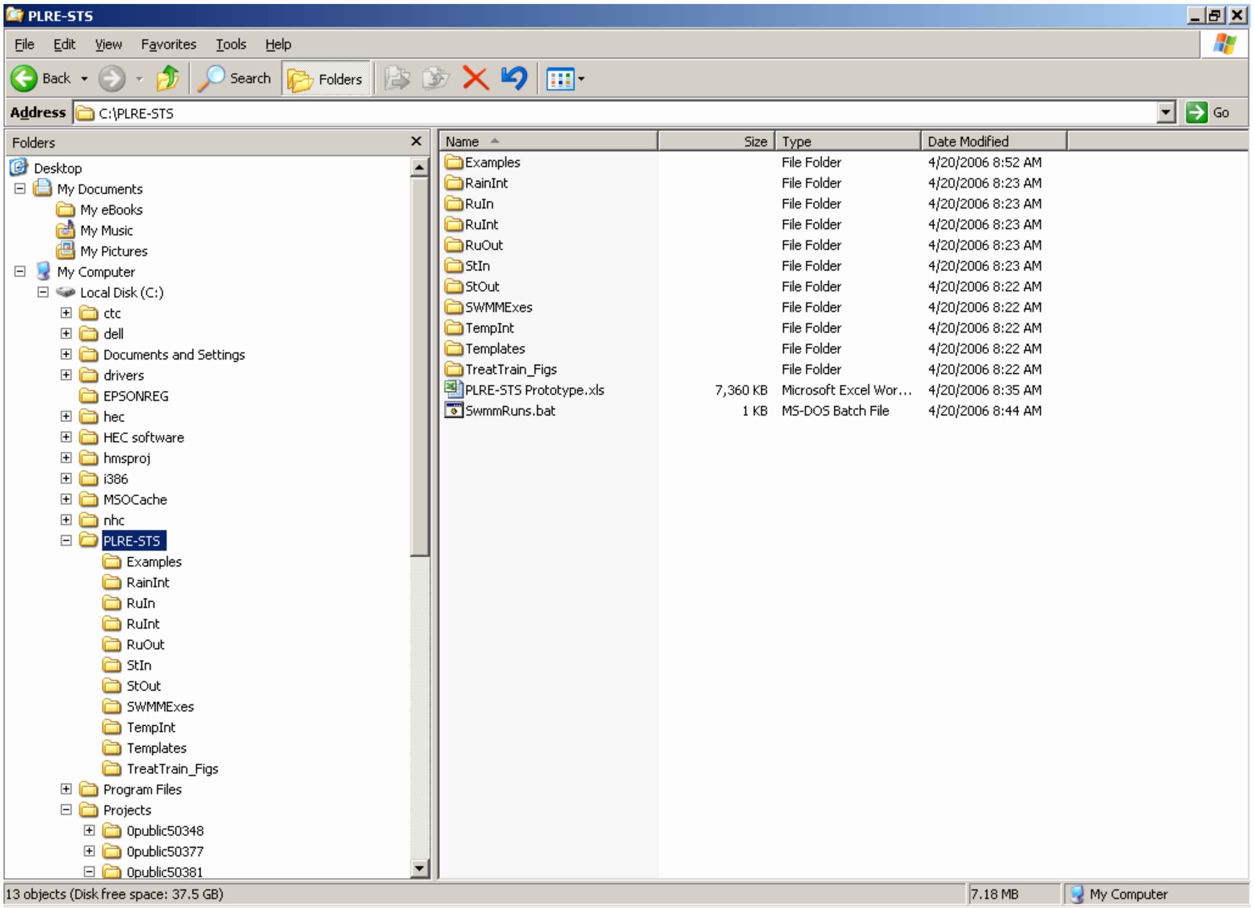

Figure A.1 – PLRE-STS Default Location and Files

To view the PLRE-STS, select and open any Excel file labeled "PLRE-STS Prototype.xls" in the **PLRE-STS** directory. When the Excel file issues a security warning; choose to **Enable Macros**. Figure A.2 displays the file **PLRE-STS.xls** after the spreadsheet is opened.

If the spreadsheet when opened on your computer screen does not match Figure A.2, make sure the tab **Input1 Hydrology** is selected and the worksheet is scrolled up to the top left corner. In the worksheet **Input1 Hydrology**, find **Table H1: Directory Structure**. In order for the PLRE-STS to run properly, the fields in **Table H1: Directory Structure** must match the pathnames for the installed PLRE-STS. In this example the directory structure for the input folders are shown below in Figure A.1 and the corresponding pathnames are listed in **Table H1** (Figure A.2). The files in **PLRE-STS.zip** can be extracted to any location, as long as the pathnames in **Table H1** are updated to reflect the directory structure. If the pathnames in **Table H1** are incorrect (i.e. do not link to the files installed on your computer) the PLRE-STS will fail to find the input files and therefore will fail to run a simulation.

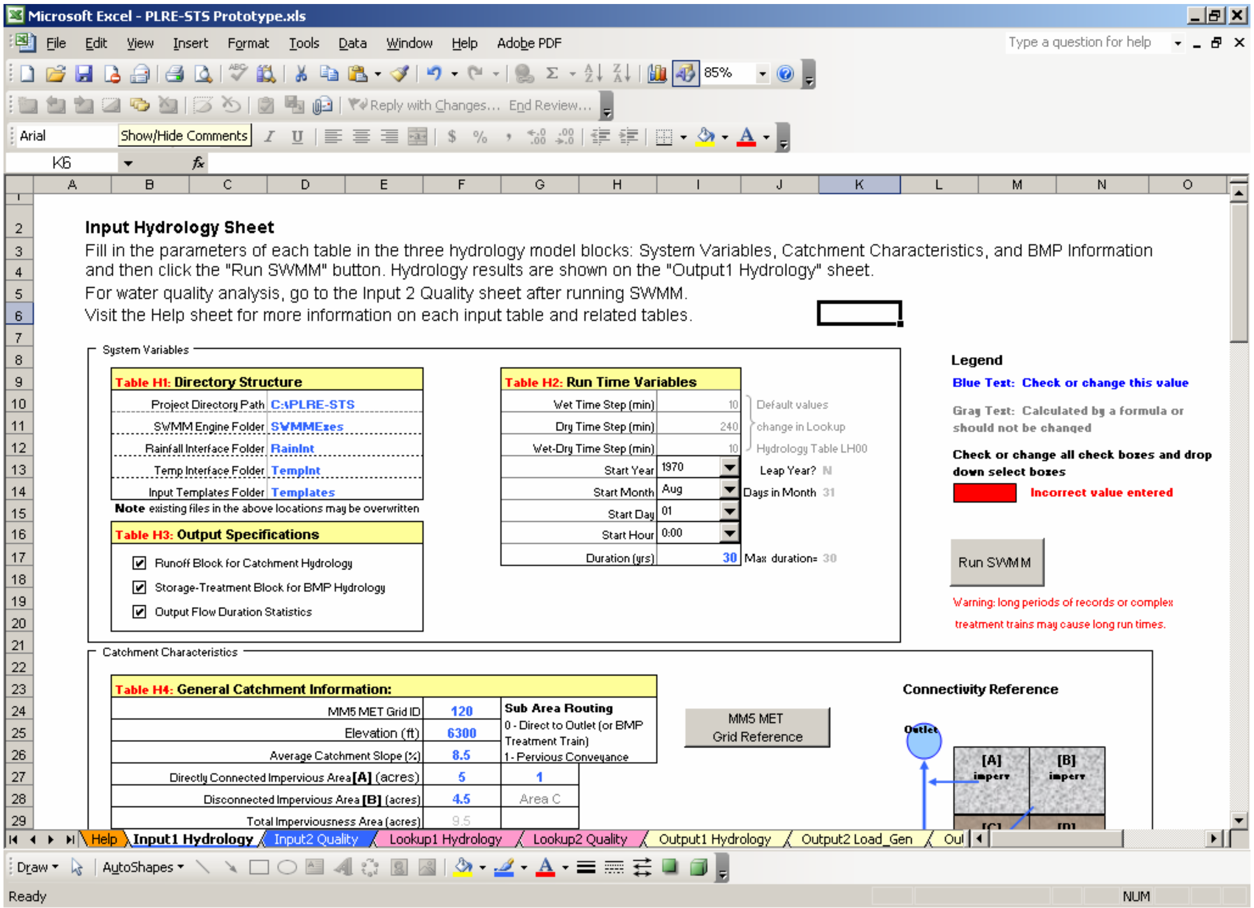

Figure A.2 – Excel Template and PLRE-STS

A.3 Input, Lookup, and Output Worksheets

Figure A.2 displays the main input screen for the PLRE-STS, **Input1 Hydrology.** Eight default Excel worksheets can be viewed by the user, as shown on the bottom tab of the spreadsheet (Figure A.2). Default worksheets include a basic help file that lists definitions for each table and field in the spreadsheet (**Help**), two input worksheets (**Input1 Hydrology** and **Input2 Quality**), two internal lookup worksheets (**Lookup1 Hydrology** and **Lookup2 Quality**), and three output worksheets (**Output1 Hydrology**, **Output2 Load_Gen**, and **Output3 Load_Red**). A discussion of each worksheet follows.

A.3.1 Help

This worksheet lists descriptions and definitions for each field included in the PLRE-STS. The user should not confuse the **Help** file provided with a typical user's help program found in more advanced software applications. The **Help** worksheet provided is only intended to clarify the purpose and units for each field in the PLRE-STS. The **Help** worksheet will not provide guidance on how to conduct a simulation or how to interpret output. Additionally, if an error is encountered the **Help** worksheet will not provide guidance on how to resolve the error. Figure A.3 displays a screen capture of the **Help** worksheet.

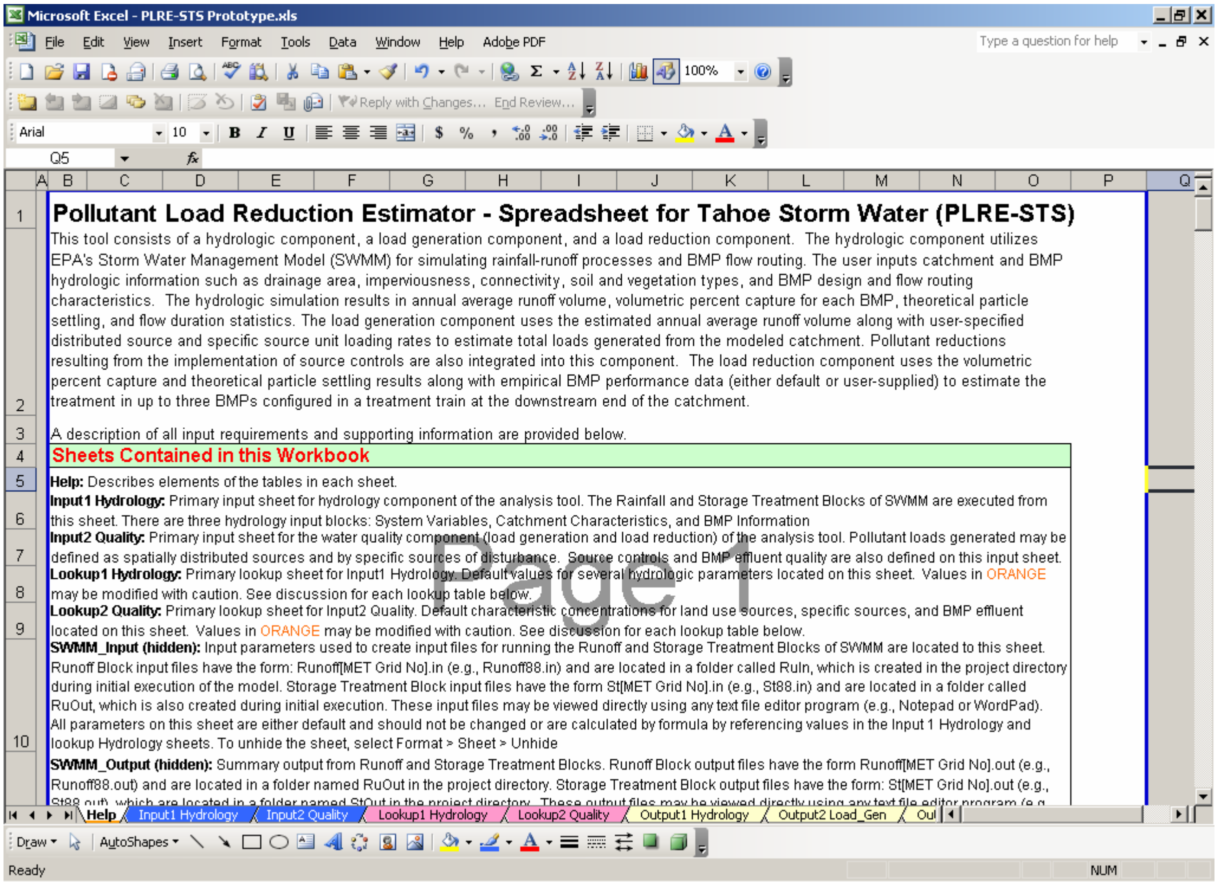

Figure A.3 – Help Worksheet

A.3.2 Input1 Hydrology

This worksheet is the primary input sheet for the hydrology component of the PLRE-STS. The Runoff and Storage Treatment Blocks of SWMM are executed from this sheet. There are three major hydrology input blocks: System Variables, Catchment Characteristics, and BMP Information. A user may run the PLRE-STS from this worksheet by clicking on the **Run SWMM** button located to the right of the **System Variables** input block in the upper right-hand corner of the spreadsheet. Figure A.2 above is a screenshot of the **Input1 Hydrology** sheet.

A user may specify the type of simulation run from this worksheet using **Table H3: Output Specifications**. By checking **Runoff Block for Catchment Hydrology** in **Table H3** the PLRE-STS will simulate precipitation and runoff for the time period selected, which is needed for the pollutant generation calculations (see Section A.3.3 - Input 2 Quality). Output data will be populated in the worksheets **Output1 Hydrology** and **Output2Load_Gen**. By checking **Storage-Treatment Block for BMP Hydrology** in **Table H3** the PLRE-STS will simulate load reductions from treatment BMPs implemented. By checking **Output Flow Duration Statistics** in **Table H3** the PLRE-STS will simulate and compare pre-treatment train and post-treatment train flow durations at the outfall.

The Catchment Characteristics input block includes the fields required to simulate runoff hydrology from a catchment. This block consists of three tables: **Table H4: General**

Catchment Information, **Table H5: Pervious Area Soils**, and **Table H6: Pervious Area Vegetation**. All required fields are colored blue. For Table H4, all of the basic catchment information, such as slope, area, and imperviousness must be provided. Notice that a modeled catchment is divided into four subareas, two impervious areas (A and B) and two pervious areas (C and D). Impervious Area A represents directly connected impervious areas and impervious area B represents indirectly connected impervious areas. Pervious area C receives runoff from area B and pervious area D is directly connected to the storm drain. In addition to the connectivity of the subareas, the user has the option to route flows from the directly connected subareas to a pervious conveyance or directly to the outlet. Figure A.4 illustrates how a catchment is represented by these four subareas and the optional pervious conveyance within the PLRE-STS.

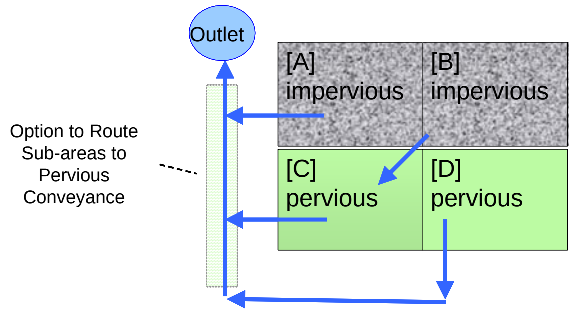

Figure A.4 – Impervious and Pervious Area Connectivity Representation.

Table H5 allows the input of surface soils information for the pervious areas in terms of percent of total pervious area. The user has the option to choose either soil texture classes or hydrologic soil groups to represent the soils at their site. Table H6 allows the input of vegetation types also in terms of percent of total pervious area. Figure A.5 shows the Catchment Characteristics input block within the **Input 1 Hydrology** sheet.

The BMP Information input block includes the fields required for simulating BMP hydraulics. Two tables are included in this block: **Table H7: BMP Routing and Loss Characteristics** and **Table H8: User Supplied Stage-Discharge**. Table H7 enables the user to model up to three BMPs in a treatment train and specify the design and routing characteristics of each BMP. Currently six different BMP types are available by default including, detention basins, wet ponds, media filters, wetland basins, hydrodynamic devices, and swales. The hydraulics of any BMP may be simulated as either flow-based or volume-based. For flow-based BMPs, hydraulic bypass occurs when the water quality design flow rate is exceeded. For volume-based BMPs, hydraulic bypass occurs when the water quality design volume is exceeded. However, a water quality design flow rate may also be specified for a volume-based BMP such that bypass may occur under either condition. Additional design parameters can be specified such as infiltration rate, geometric parameters, and outlet controls. If the user specifies the "user-supplied" stage-discharge for any of the simulated BMPs, then the stage-area-discharge relationship must be provided in Table H8 for each BMP specified. Figure A.6 is a screenshot of the BMP Information block within the **Input 1 Hydrology** sheet.

Additional guidance on hydrologic input parameters and background information is provided in the **Help** sheet and the main text of the report.

Catchment Characteristics

Table H4: General Catchment Information:

		Sub Area Routing 0 - Direct to Outlet (or BMP Treatment Train) 1 - Pervious Conveyance
MM5 MET Grid ID	127	
Elevation (ft)	6360	
Average Catchment Slope (%)	7	
Directly Connected Impervious Area [A] (acres)	9	0
Disconnected Impervious Area [B] (acres)	11	Area C
Total Imperviousness Area (acres)	20	
Perv Area Receiving Imperv Runoff [C] (acres)	10.5	1
Perv Area Not Receiving Runoff [D] (acres)	25.5	1
Total Pervious Area (acres)	36	
Catchment Area (acres)	56.0	
Representative Pervious Conveyance Length (ft)	2000	
Primary Conveyance Slope (%)	7	
Primary Conveyance Saturated Loss Rate (in/hr)	0.05	

MM5 MET Grid Reference

Connectivity Reference

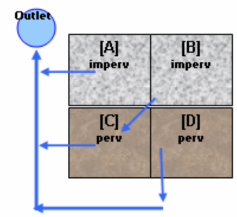

Table H5: Pervious Area Soils

☐ Texture Class ☑ Hydrologic Soil Group

Texture Class	% of Total Perv Area	HSG	% of Total Perv Area
Sand	0%	A	0%
Loamy Sand	0%	B	0%
Sandy Loam	100%	C	100%
Loam	0%	D	0%
Silt Loam	0%	Check Sum	100%
Sandy Clay Loam	0%		
Clay Loam	0%		
Silty Clay Loam	0%		
Sandy Clay	0%		
Silty Clay	0%		
Clay	0%		
UserDefined1	0%		
UserDefined2	0%		
UserDefined3	0%		
Check Sum			

WARNING: If your site-specific soil texture class is not adequately represented here either enter user-defined soil parameters in Table LH3 in the Lookup1 Hydrology sheet or use the hydrologic soil group. Refer to the current soil survey or conduct site-specific soil tests if you are not sure of the soil type in your area.

Table H6: Pervious Area Vegetation

Veg. Cover	% of Total Perv Area
Shrub	10%
Herbaceous	10%
Tree (open canopy)	50%
Tree (closed canopy)	0%
Non-vegetated	30%
UserDefined1	0%
UserDefined2	0%
UserDefined3	0%
UserDefined4	0%
UserDefined5	0%
Check Sum	100%

Figure A.5 – Catchment Characteristics for the Input1 Hydrology Worksheet

BMP Information

Flow-Based BMP Info

Volume-Based BMP Info

Table H7: BMP Routing and Loss Characteristics

General Data:				
Storage-Treatment Time Step (min)	10	<= Default value change only in Lookup Hydrology Table LH00		
		Upstream to Downstream		
Treatment Train Configuration:	**BMP1**	**BMP2**	**BMP3**	
BMPs Simulated	Yes	No	No	
BMP Type	Detention Basin	Detention Basin	Biofiltration Swale/Strip	
BMP Hydraulics	Volume-Based	Volume-Based	Flow-Based	
Bypass flow routed to	Outlet	Outlet	Outlet	
Treated flow routed to	Outlet	Outlet	Outlet	
BMP Loss Rate (in/hr)	0.1	0	0	Required for flow-based;optional for volume-based
WQ Design Flow Rate, Q_{design} (cfs)	0	0	0	<= (set to zero if not used)
Length to width ratio	1.5	1	1	<= Must be greater than zero
Additional Parameter Required for Flow-Based BMPs				
Characteristic Footprint Area (sf)	0	0	10000	<= Effective area for which losses may occur, must be greater than zero
Additional Parameters Required for Volume-Based BMPs				
Water Quality Design Volume (cu-ft)	20400	2000	0	<= **NOT** including wet pool.
Permanent Wet Pool Volume (cu-ft)	0	0	0	
Permanent Wet Pool Depth (ft)	0	0	0	
WQ Design Depth (live storage) (ft)	3.5	4	0	
Total Basin Depth (ft)	3.5	4	0	
BMP Stage-Discharge	User-Supplied	Default	Default	For User-Supplied, discharge should be zero up to the top of the wet pool volume and final depth should equal the total basin depth
Brim-Full Draw Down Time (hours)	24	36	24	

MODIFY these tables if the BMP Stage-Discharge drop down select box is switched to "**USER-SUPPLIED**".

Table H8-1: User-Supplied Stage-Discharge for BMP 1

Depth	Area	Outflow
(ft)	(ft^2)	(cfs)
0.0	500	0
0.10	414	0.05

Table H8-2: User-Supplied Stage-Discharge for BMP 2

Depth	Area	Outflow
(ft)	(ft^2)	(cfs)
0.0	3000	0
1.0	3000	0.045990989

Table H8-3: User-Supplied Stage-Discharge for BMP 3

Depth	Area	Outflow
(ft)	(ft^2)	(cfs)
0.0	1000	0
0.3	1000	0.2

Figure A.6 – BMP Information for the Input1 Hydrology Worksheet

A.3.3 Input2 Quality

This worksheet contains the fields for all user required water quality input to simulate pollutant load generation and pollutant source control. A user may specify pollutant generation from spatially distributed sources (land use based) and specific sources (road sanding, disturbed areas, and gully erosion). The user may also choose between various pollutant source control practices, such as conveyance system stabilization, road shoulder stabilization, BMP maintenance, road sand recovery, and disturbed area erosion control. This input sheet also includes a summary of BMP performance (effluent quality) values for the BMPs chosen in the **Input1 Hydrology**. Spatially distributed load generation and load removals in downstream BMPs are directly dependent on the results of the hydrologic simulation, while specific source loads are not. However, if the hydrologic simulation has already been completed, the user may evaluate different pollutant source control scenarios (distributed or specific) without rerunning SWMM. The following paragraphs briefly describe the water quality input tables.

Table Q1: Spatially Distributed Source Accounting - Landuse Based and **Table Q2: Spatially Distributed Source Controls Accounting** provide land use based techniques for estimating pollutant loading for the existing conditions and after spatially distributed source control implementation. For a distributed pollutant source loading simulation, the user must specify the land use types, the percent of the total area that the land uses consists of, and the average percent imperviousness of the land uses. For distributed source controls, the user must also specify the management tiers (or relative effectiveness index) for each type of land use based distributed source control. Refer to the **Help** sheet and the main text for information on the distributed sources and management tiers. Figure A.7 shows the layout of Tables Q1 and Q2.

Table Q1: Spatially Distributed Source Accounting - Landuse Based

	Area Breakdown		Constant Characteristic Concentration					
Land Use Category	% of Total Area	Average % Imperviousness	NO3-N (mg/L)	TKN (mg/L)	SRP (mg/L)	TP (mg/L)	TSS (mg/L)	Fine Sed <20 micron (% TSS)
Roads - Primary	6%	90%	3.613	0.663	1.823	0.088	876	63%
CICU - Commercial, Institutior	29%	65%	1.914	0.227	0.543	0.060	229	63%
Residential - Single Family	59%	30%	1.154	0.095	0.308	0.095	37	36%
Veg_ep3	6%	0%	0.164	0.011	0.034	0.029	34	30%
User Defined 1	0%	0%	0.000	0.000	0.000	0.000	1	10%
User Defined 1	0%	0%	0.000	0.000	0.000	0.000	1	10%
User Defined 2	0%	0%	0.000	0.000	0.000	0.000	2	10%
User Defined 3	0%	0%	0.000	0.000	0.000	0.000	3	10%
User Defined 4	0%	0%	0.000	0.000	0.000	0.000	4	10%
Sum	100%							

Table Q2: Spatially Distributed Source Controls Accounting

	Relative Effective Index					
Land Use Category	Stablized Conveyance System	Road Shoulders Stabilized	BMP Maintenance	Other 1	Other 2	Percent of Default EMC
Roads - Primary	Null	Null	Tier 1	Null	Null	92%
CICU - Commercial, Institutior	Tier 1	Null	Tier 2	Null	Null	77%
Residential - Single Family	Tier 2	Tier 2	Tier 1	Null	Null	66%
Veg_ep3	Null	Null	Null	Null	Null	100%
User Defined 1	Null	Null	Null	Null	Null	100%
User Defined 1	Null	Null	Null	Null	Null	100%
User Defined 2	Null	Null	Null	Null	Null	100%
User Defined 3	Null	Null	Null	Null	Null	100%
User Defined 4	Null	Null	Null	Null	Null	100%

Figure A.7 – Spatially Distributed Source Accounting Tables in Input2 Quality Sheet.

Table Q3: Specific Source Accounting - Road Sanding, Table Q4: Specific Source Accounting - Surficial Erosion from Disturbed Areas, and **Table Q5: Specific Source Accounting - Gully and Channel Erosion** provide specific source accounting techniques for estimating pollutant loadings for the existing conditions and after specific source control implementation. The road sanding input parameters (Table Q3) include the sand application rate, total area of source, and the average annual percent recovery. The input parameters for surficial erosion and disturbed source areas (Table Q4) primarily includes Universal Soil Loss Equation parameters, such as soil condition, total area of source, percent delivery to the drainage system, overland flow length, slope, erodibility, and vegetative cover. The user also has an option to override the USLE calculation method and provide an annual sediment load for each disturbed area. The gully and channel erosion input parameters (Table Q5) includes the direction of erosional advancement, mean annual erosion rate, percent delivery to the drainage system, and the length, width, and depth of the eroded gully. As with the disturbed areas, the user has the option to override the gully erosion method and provide an annual sediment load for each gully. Refer to the **Help** sheet and the main text for more guidance on estimating specific source parameters. Figure A.8 shows the layout of Tables Q3.

Table Q3: Specific Source Accounting - Road Sanding

Sand Application Rate	Total Area of Source (ft²)	Average Annual Percent Recovery	NO3-N (lbs/year)	TKN (lbs/year)	SRP (lbs/year)	TP (lbs/year)	TSS (lbs/year)	Fine Sed <20 (lbs/year)
			Annual Loads from Specific Source - Road Sanding					
Average Road Sanding	10,000	80%	0.00	0.01	0.00	0.56	2,300	1449
Heavy Road Sanding	0	0%	0.00	0.00	0.00	0.00	-	0
Heavy Road Sanding	0	0%	0.00	0.00	0.00	0.00	-	0

Table Q4: Specific Source Accounting - Surficial Erosion from Disturbed Areas

	USLE Method						User Defined	Annual Loads from Specific Sources - Disturbed Areas					
Soil Condition	Total Area of Source (ft²)	Percent Delivery to Drainage System	Overland Flow Length (ft)	Average Slope (%)	Soil Erodibility (K Factor)	Percent Vegetative Ground Cover	TSS Load (lbs/year) Overrides USLE Method	NO3-N (lbs/year)	TKN (lbs/year)	SRP (lbs/year)	TP (lbs/year)	TSS (lbs/year)	Fine Sed <20 (lbs/year)
Compacted Soil	10,000	50%	50	7%	0.35	20%	0	0.0	0.3	0.0	0.2	276.1	82.8
Smooth Surface - Loose Soil	0	0%	0	0%	0.00	0%	0	0.0	0.0	0.0	0.0	0.0	0.0
Smooth Surface - Loose Soil	0	0%	0	0%	0.00	0%	0	0.0	0.0	0.0	0.0	0.0	0.0
Smooth Surface - Loose Soil	0	0%	0	0%	0.00	0%	0	0.0	0.0	0.0	0.0	0.0	0.0
User Defined 2	0	0%	0	0%	0.00	0%	0	0.0	0.0	0.0	0.0	0.0	0.0

Table Q5: Specific Source Accounting - Gully and Channel Erosion

	Gully and Channel Method						User Defined	Annual Loads from Specific Source - Gully and Channel Erosion					
Gully or Channel	Primary Direction of Erosional Advancement	Mean Annual Rate of Erosion (ft/yr)	Average Annual Percent Delivery to Drainage System	Current Length (ft)	Current Average Width (ft)	Current Average Depth (ft)	TSS Load (lbs/year) Overrides Gully Method	NO3-N (lbs/year)	TKN (lbs/year)	SRP (lbs/year)	TP (lbs/year)	TSS (lbs/year)	Fine Sed <20 (lbs/year)
Gully 1	Length	0.0	50%	20.0	3.0	3.0	0	0	0	0	0	0	0
Gully 2	Depth	0.0	60%	10.0	5.0	2.0	0	0	0	0	0	0	0
Gully 3	Width	0.0	60%	10.0	5.0	2.0	0	0	0	0	0	0	0

Figure A.8 – Specific Source Accounting Tables in Input2 Quality Worksheet.

Table Q6: Characteristic Effluent Quality Concentrations for BMPs may not be edited in this table, but provides a check for the user to review characteristic effluent concentrations used by the PLRE-STS if storm water treatment BMPs are selected in the **Input1 Hydrology** worksheet. Figure A.9 shows the layout of Table Q6 in the Input2 Quality Worksheet.

Table Q6: Characteristic Effluent Quality Concentrations for BMPs

BMP No.	BMP Type	NO3-N (mg/L)	TKN (mg/L)	SRP (mg/L)	TP (mg/L)	TSS (mg/L)	Fine Sed <20 (mg/L)	BMP Hydraulics
BMP1	Detention Basin	0.68	1.50	0.07	0.29	32.00	NA	Volume-Based
BMP2	Detention Basin	0.68	1.50	0.07	0.29	32.00	NA	Volume-Based
BMP3	Biofiltration Swale/Strip	0.28	1.43	0.05	0.24	22.00	NA	Flow-Based

Figure A.9 – Characteristic BMP Effluent Concentrations Table in Input2 Quality Worksheet.

A.3.4 Lookup1 Hydrology

This worksheet contains lookup hydrologic data used during the hydrologic simulation. This data does not need to be modified by the user and in most cases modifications to lookup hydrologic data is not recommended. The tables in **Lookup1 Hydrology** are included in the event new data become available that may refine and improve the simulation. The lookup tables may be modified based on best professional judgment if a user believes the lookup data does not accurately depict their project catchment or a user would like to investigate the sensitivity of particular parameters. The location of tables and fields should never be modified because internal cross-referencing of spreadsheet cells may be lost. Figure A.10 displays a screen capture of the **Lookup1 Hydrology** worksheet. The fields in Figure A.10 that are color coded in **orange** are default values that may be changed by the user. Changing default values is generally not recommended unless the user is very familiar with the structure of the tool and is an experienced hydrologic modeler. Refer to the **Help** sheet for information on the individual tables and fields in the **Lookup1 Hydrology** sheet.

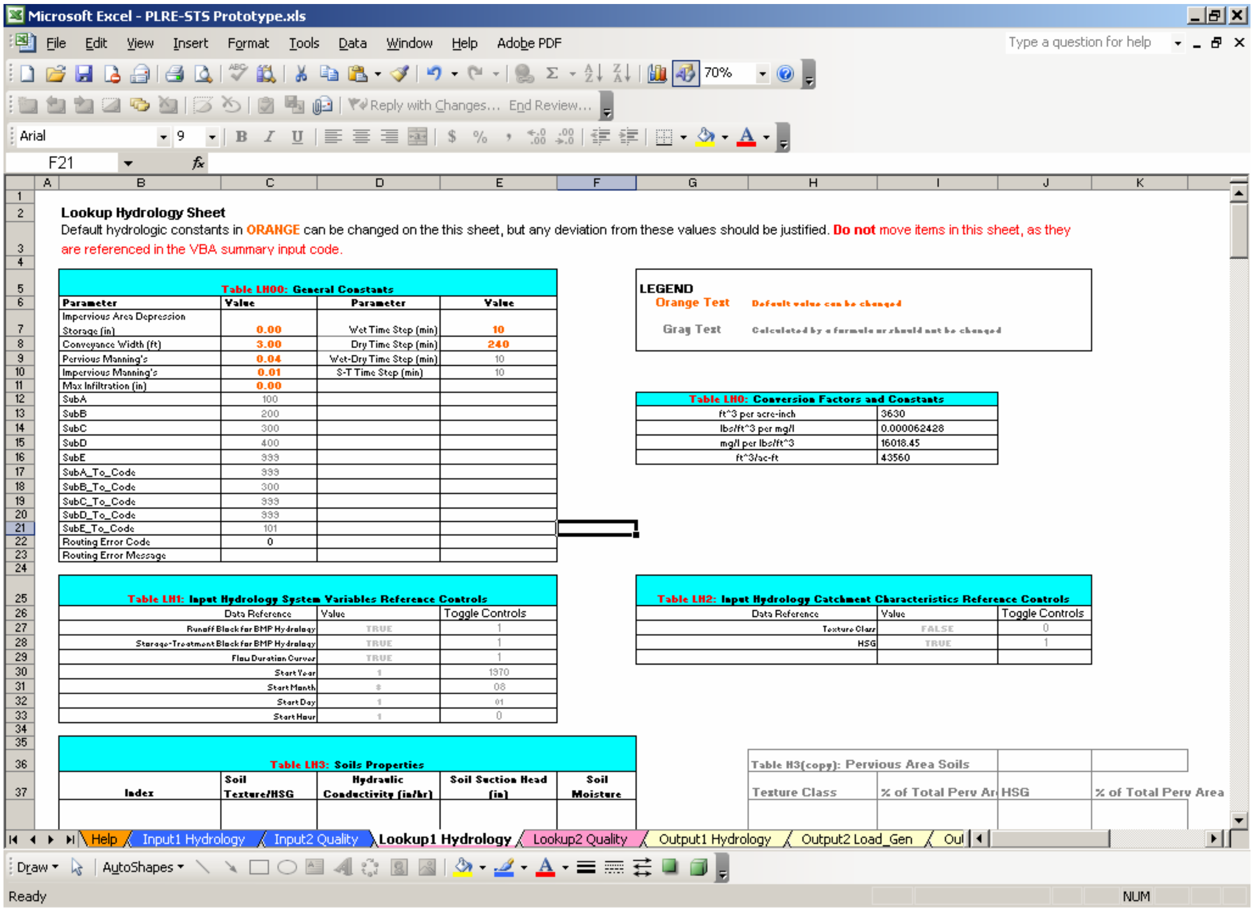

Figure A.10 – Lookup1 Hydrology Worksheet

A.3.5 Lookup2 Quality

This worksheet contains lookup water quality data used during the pollutant load generation and pollutant load reduction simulations. This data does not need to be modified by the user and in most cases modifications to lookup water quality data is not recommended. The tables in **Lookup 2 Quality** are included in the event new or additional data become available for runoff quality and BMP performance in Lake Tahoe. The lookup tables may be modified based on best professional judgment if a user believes the lookup data does not accurately depict their project catchment or if a user would like to investigate the sensitivity of particular parameters. Figure A.11 displays a screen capture of the **Lookup2 Quality** worksheet. Fields in Figure A.11 that are color coded in orange are default values that may be changed by the user. Changing default values is generally not recommended.

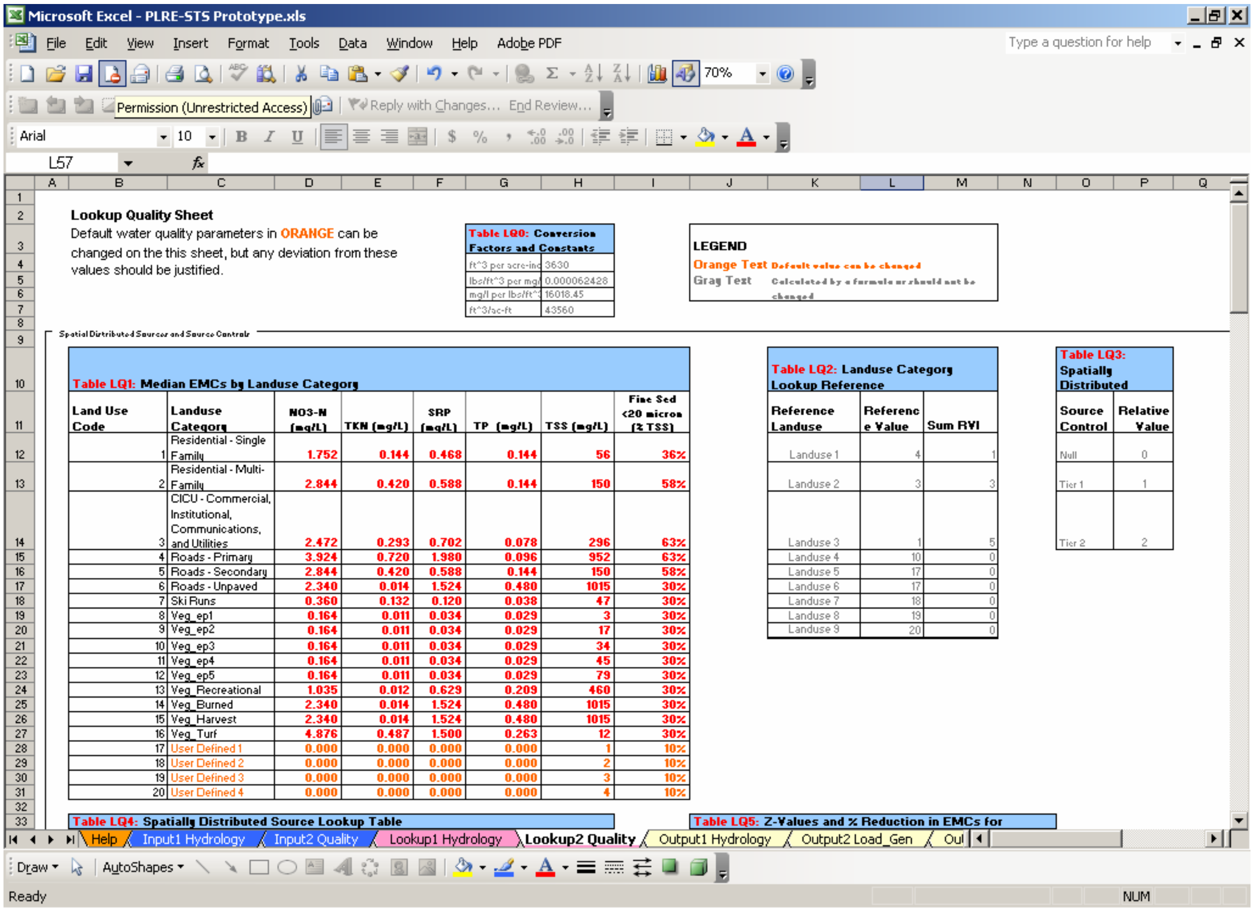

Table LQ1: Median EMCs by Landuse Category

Land Use Code	Landuse Category	NO3-N (mg/L)	TKN (mg/L)	SRP (mg/L)	TP (mg/L)	TSS (mg/L)	Fine Sed <20 micron (% TSS)
1	Residential - Single Family	1.752	0.144	0.468	0.144	56	36%
2	Residential - Multi-Family	2.844	0.420	0.588	0.144	150	58%
3	CICU - Commercial, Institutional, Communications, and Utilities	2.472	0.293	0.702	0.078	296	63%
4	Roads - Primary	3.924	0.720	1.980	0.096	952	63%
5	Roads - Secondary	2.844	0.420	0.588	0.144	150	58%
6	Roads - Unpaved	2.340	0.014	1.524	0.480	1015	30%
7	Ski Runs	0.360	0.132	0.120	0.038	47	30%
8	Veg_ep1	0.164	0.011	0.034	0.029	3	30%
9	Veg_ep2	0.164	0.011	0.034	0.029	17	30%
10	Veg_ep3	0.164	0.011	0.034	0.029	34	30%
11	Veg_ep4	0.164	0.011	0.034	0.029	45	30%
12	Veg_ep5	0.164	0.011	0.034	0.029	79	30%
13	Veg_Recreational	1.035	0.012	0.629	0.209	460	30%
14	Veg_Burned	2.340	0.014	1.524	0.480	1015	30%
15	Veg_Harvest	2.340	0.014	1.524	0.480	1015	30%
16	Veg_Turf	4.876	0.487	1.500	0.263	12	30%
17	User Defined 1	0.000	0.000	0.000	0.000	1	10%
18	User Defined 2	0.000	0.000	0.000	0.000	2	10%
19	User Defined 3	0.000	0.000	0.000	0.000	3	10%
20	User Defined 4	0.000	0.000	0.000	0.000	4	10%

Table LQ2: Landuse Category Lookup Reference

Reference Landuse	Reference Value	Sum RVI
Landuse 1	4	1
Landuse 2	3	3
Landuse 3	1	5
Landuse 4	10	0
Landuse 5	17	0
Landuse 6	17	0
Landuse 7	18	0
Landuse 8	19	0
Landuse 9	20	0

Figure A.11 – Lookup2 Quality Worksheet

A.3.6 Output1 Hydrology

This worksheet is populated with summary hydrologic data after a PLRE-STS simulation has been successfully completed. The output is based upon the following selections in **Table H3: Output Specifications** in the worksheet **Input1 Hydrology**.

Checking **Runoff Block for Catchment Hydrology** will populate **Table OH1: Hydrologic Continuity Results** and **Table 0H2: Pervious/Impervious Area Results**. Output from these tables describes precipitation and runoff characteristics from the catchment as shown in Figure A.12.

Table OH1: Hydrologic Continuity Results

Parameter	Total Period of Record (ac-ft)	Average Annual (ac-ft)	Average Annual (inches)
Total Rain&Snow	1627.66	54.26	11.63
Rain Only	839.94	28.00	6.00
Snow Only (water equivalent)	787.71	26.26	5.63
Water Remaining in Surface Storage	0.00	0.00	0.00
Water Remaining in Snow	0.00	0.00	0.00
Total Loss Due to Infiltration	1069.75	35.66	7.64
Total Loss Due to Evapotranspiration	158.43	5.28	1.13
Total Runoff Volume	322.01	10.73	2.30
Percent Runoff (%)	0.20	19.8%	19.8%

Table 0H2: Pervious/Impervious Area Results (Annual Averages)

Area	Area (ac)	Simulated Precip (ac-ft)	Run-On (ac-ft)	Loss (ac-ft)	Runoff (ac-ft)	Routed To	Volume to Outlet (ac-ft)
A (imp)	9.00	8.72	0.00	0.97	7.75	Outlet	7.75
B (imp)	11.00	10.66	0.00	1.21	9.45	C	0.00
C (perv)	10.50	10.17	9.45	17.66	1.97	Outlet	1.97
D (perv)	25.50	24.71	0.00	23.69	1.02	Outlet	1.02
E (conveyance)	0.00	0.00	0.00	0.00	0.00	Outlet	0.00
Total Catchment	56.00	54.26		43.52			10.73

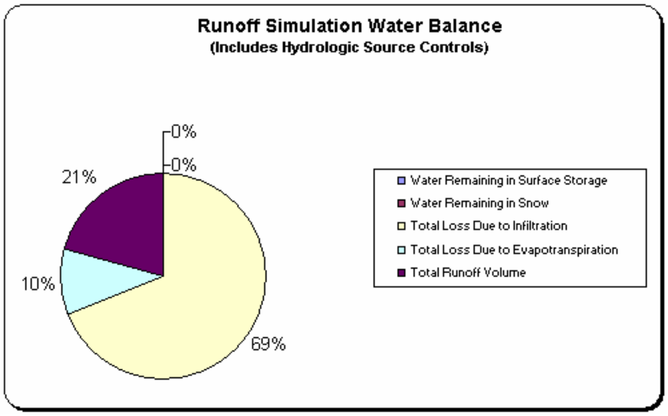

Figure A.12 – Example Catchment Hydrology Output Information.

Checking **Storage-Treatment Block for BMP Hydrology** will populate **Table OH3: BMP Percent Capture and Hydraulic Performance Statistics** and **Table OH4: Sedimentation Treatment Results by Particle Size**. Output from these tables describes hydraulic characteristics of the storm water treatment BMPs as well as predicted fine sediment removal by particle size classes. Note that storm water treatment BMPs must be designed and simulated in **Input1 Hydrology** in order to populate output tables. If the Runoff Block for Catchment Hydrology is not checked, results from a previous Runoff Block simulation must be available before a Storage-Treatment Block simulation can occur. This feature allows the user to modify characteristics of their BMP treatment train without re-running the catchment hydrology. Figure A.13 is an example of the BMP hydraulic output tables. Notice that in addition to the average annual water balance statistics for each BMP, the average retention time for the entire period of record is provided. Fine particle settling results are included in the summary information since these data are part of the Storage Treatment Block simulation.

Table OH3: BMP Percent Capture (Annual Averages) and Hydraulic Performance Statistics

	Total Inflow (ac-ft)	Bypass (ac-ft)	Treated (ac-ft)	ET (ac-ft)	Infiltration (ac-ft)	% Capture	% Vol Loss	Bypassed Flows To	Treated Flows To	Brim Full Drawdown Time (hrs)	Average Retention Time (hrs)
BMP 1: Volume-Based	10.73	0.81	8.82	0.05	1.06	92.5%	11.1%	BMP2	BMP3	73	10.36
BMP 2: Volume-Based	0.81	0.68	0.12	0.00	-	15.1%	0.2%	Outlet	BMP3	36	9.10
BMP 3: Flow-Based	8.94	0.89	7.93	0.12	-	90.0%	1.5%	Outlet	Outlet	NA	0.16

Table OH4: Sedimentation Treatment Results by Particle Size

		BMP1	BMP2	BMP3	Overall
Pollutant Name	Size Range (um)	% Treated	% Treated	% Treated	% Treated
TSS1	0-4	3.0%	1.4%	14.8%	8.6%
TSS2	4-8	18.7%	9.1%	51.1%	33.9%
TSS3	8-12	46.0%	29.5%	55.9%	50.5%
TSS4	12-16	62.7%	56.0%	47.2%	55.4%
TSS5	16-20	71.1%	74.1%	44.1%	58.4%
Total Fine Sediment	**<20**	**40%**	**34%**	**43%**	**41%**

Figure A.13 – Example BMP Hydraulics Output Information.

Checking Output Flow Duration Statistics in Table H3 of the **Input1 Hydrology** sheet will populate **Table OH5: Flow Duration Results** and the associated pre-treatment train and post-treatment train flow duration figure. Flow duration results describe the amount of time that various flow rates were exceeded over the entire simulated period of record. This information is useful for evaluating potential hydromodification impacts on receiving waters due to catchment development or storm water management control strategies. Output from this table and figure describes the change in flow durations seen prior to entering a BMP treatment train and at the outfall of the BMP treatment train. Figure A.14 is an example of the flow duration output information provided by the PLRE-STS.

Table OH5: Flow Duration Results

Pre-Treatment Train		Post-Treatment Train	
Flow Rate	Hours of Flow Greater Than Or Equal To Flow Rate	Flow Rate	Hours of Flow Greater Than Or Equal To Flow Rate
0.00	27461.91	0.00	44658.73
0.10	7076.60	0.10	951.56
0.20	3013.86	0.20	702.56
0.30	1531.81	0.30	471.23
0.40	1009.38	0.40	383.23
0.50	762.02	0.50	340.23
0.60	599.02	0.60	311.56
0.70	498.52	0.70	290.90
0.80	431.85	0.80	272.40
0.90	386.34	0.90	262.06
1.00	348.18	1.00	252.73
1.10	322.67	1.10	239.40
1.20	299.67	1.20	228.06
1.30	278.51	1.30	216.90
1.40	257.01	1.40	206.73
1.50	240.67	1.50	198.56
1.60	229.67	1.60	191.40
1.70	218.34	1.70	183.73
1.80	209.34	1.80	176.90
1.90	203.01	1.90	169.90
2.00	193.17	2.00	159.73
2.10	182.34	2.10	154.56
2.20	176.33	2.20	149.73
2.30	168.50	2.30	146.73
2.40	162.67	2.40	143.06
2.50	158.67	2.50	140.06
2.60	152.33	2.60	135.56

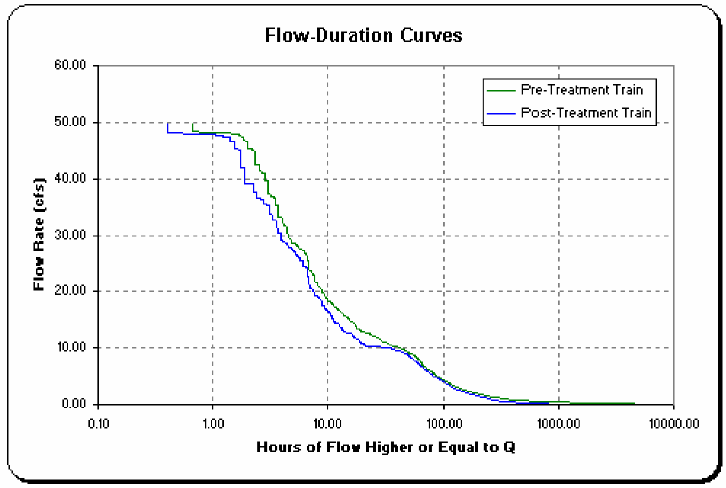

Figure A.14 – Example Flow Duration Output Information.

A.3.7 Output2 Load_Gen

This worksheet will be populated with pollutant load generation output summary statistics based on a successful PLRE-STS simulation of runoff hydrology (SWMM Runoff Block) and the appropriate input of pollutant source and source control information in **Input 2 Quality**. Tables in **Output2 Load_Gen** describe load generated from spatially distributed sources and specific sources.

As noted above, once a hydrology simulation has run, water quality input data may be altered in the worksheet **Input2 Quality** without the need to rerun a hydrology simulation. Water quality output updates immediately in worksheets **Output2 Load_Gen** and **Output3 Load_Red** as long as hydrologic characteristics have not changed**.** If hydrologic information is altered, the PLRE-STS must be re-run before viewing and analyzing any output for hydrology, pollutant load generation, or pollutant load reduction. Tables OLG1 and OLG2 summarize the land use EMCs used and the computed annual average loads, respectively, for distributed sources. Table OLG3 summarizes the estimated loads from specific sources and Table OLG4 summarizes the total loads from all sources at the downstream end of the catchment before entering a BMP treatment train. Figures A.15 and A.16 are example output tables included in the **Output2 Load_Gen** worksheet.

Table OLG1: EMCs from Distributed Sources									
	Average Annual Runoff		Pollutant Concentrations from Land Uses						
Land Use	% of Runoff	Runoff Volume (ac-ft)	NO3-N (mg/L)	TKN (mg/L)	SRP (mg/L)	TP (mg/L)	TSS (mg/L)	Fine Sed <20 micron (% TSS)	Fine Sed <20 um (mg/L)
Mod-Disturbance Open Space	2.1%	0.23	0.07	1.00	0.06	0.28	32	30%	9.5
Mod-Disturbance Open Space	4.4%	0.47	0.07	1.00	0.06	0.28	32	30%	9.5
Highway	51.1%	5.48	0.23	3.05	0.06	1.65	793	63%	499.6
Mod-Disturbance Open Space	42.5%	4.56	0.07	1.00	0.06	0.28	32	30%	9.5
User Defined1	0.0%	0.00	1.00	1.00	1.00	1.00	1	30%	0.3
User Defined1	0.0%	0.00	1.00	1.00	1.00	1.00	1	30%	0.3
Residential 1	0.0%	0.00	0.10	1.36	0.07	0.39	47	39%	18.1
Residential 1	0.0%	0.00	0.10	1.36	0.07	0.39	47	39%	18.1
User Defined2	0.0%	0.00	0.14	2.27	0.08	1.03	251	30%	75.3
TOTALS	100.0%	10.73							

Table OLG2: Average Annual Loads From Distributed Sources								
	Runoff		Pollutant Loads from Land Uses					
Land Use	% of Runoff	Runoff Volume (ac-ft)	NO3-N (lbs)	TKN (lbs)	SRP (lbs)	TP (lbs)	TSS (lbs)	Fine Sed <20 um (lbs)
Mod-Disturbance Open Space	2.1%	0.23	0.04	0.61	0.03	0.17	19.5	5.8
Mod-Disturbance Open Space	4.4%	0.47	0.09	1.27	0.07	0.35	40.4	12.1
Highway	51.1%	5.48	3.35	45.38	0.82	24.52	11819	7446
Mod-Disturbance Open Space	42.5%	4.56	0.85	12.35	0.70	3.45	392.5	117.8
User Defined1	0.0%	0.00	0.00	0.00	0.00	0.00	0.0	0.0
User Defined1	0.0%	0.00	0.00	0.00	0.00	0.00	0.0	0.0
Residential 1	0.0%	0.00	0.00	0.00	0.00	0.00	0.0	0.0
Residential 1	0.0%	0.00	0.00	0.00	0.00	0.00	0.0	0.0
User Defined2	0.0%	0.00	0.00	0.00	0.00	0.00	0.0	0.0
TOTALS	100.0%	10.73	4.33	59.62	1.62	28.49	12271	7582

Figure A.15 – Distributed Source Output Tables in Output2 Load_Gen Worksheet

Table OLG3: Average Annual Loads From Specific Sources								
			Pollutant Loads from Specific Sources					
Specific Sources			NO3-N (lbs)	TKN (lbs)	SRP (lbs)	TP (lbs)	TSS (lbs)	Fine Sed <20 micron (lbs)
Average Road Sanding			0	0	0	1	2,300	1,449
Heavy Road Sanding			0	0	0	0	0	0
Heavy Road Sanding			0	0	0	0	0	0
Compacted Soil			0	0	0	0	276	83
Smooth Surface - Loose Soil			0	0	0	0	0	0
Smooth Surface - Loose Soil			0	0	0	0	0	0
Smooth Surface - Loose Soil			0	0	0	0	0	0
User Defined 2			0	0	0	0	0	0
Gully 1			0	0	0	0	0	0
Gully 2			0	0	0	0	0	0
Gully 3			0	0	0	0	0	0
TOTALS			0	0	0	1	2576	1532

Table OLG4: Summary of Average Annual Loads From All Sources								
	Annual Average Runoff		Total Pollutant Loads to BMP1 Including Specific Sources					
Land Use	% Runoff	Runoff Volume (ac-ft)	O3-N (lbs	TKN (lbs)	SRP (lbs)	TP (lbs)	TSS (lbs)	Fine Sed <20 um (lbs)
Total Load from Land Uses		10.73	4	60	2	28	12,271	7,582
Total Load from Specific Sources			0	0	0	1	2,576	1,532
TOTAL RUNOFF LOADS	19.8%	**10.73**	**4**	**60**	**2**	**29**	**14,847**	**9,113**

Figure A.16 – Specific Source and Load Summary Tables in Output2 Load_Gen Worksheet

A.3.8 Output3 Load_Red

This worksheet will be populated with annual average BMP pollutant loading and removal statistics after a successful PLRE-STS simulation of BMP hydraulics (SWMM Storage-Treatment Block) for the BMP types selected in **Input1 Hydrology** sheet**.** Output and routing of runoff is based on the BMP hydrologic design information entered in **Table H7: BMP Routing and Loss Characteristics.** Up to three BMPs may be simulated in series or in parallel at the outfall of a catchment. Influent pollutant loading into the first BMP in the table **Output3 Load_Red** is the total load generation from **Output2 Load_Gen.** Effluent pollutant loading is calculated based on the influent loading, volume losses, and characteristic effluent quality concentrations of the BMP type simulated. Pollutant loading for bypassed runoff is assumed to equal influent loading. As such, the treatment train configuration has a direct influence on the ultimate load reductions estimated at the outlet. A figure is provided on this worksheet, upon a successful execution of the Storage Treatment Block, which summarizes the chosen treatment train configuration. Table OLR1 is used to summarize the annual average loading results at each stage of the treatment train and the final effluent to receiving waters. Estimated cumulative percent reductions are also included at each stage of the treatment train as a means for evaluating the added benefit of including these additional BMPs in the treatment train. Figure A.17 is an example of the results provided in the **Output3 Load_Red** worksheet.

Treatment Train Configuration

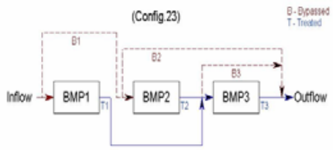

Table OLR1: Average Annual Influent and Effluent Loads and Concentrations from Centralized BMPs

	Runoff		Pollutant Loads from All Sources					
	Routing	Runoff Volume (ac-ft)	NO3-N (lbs)	TKN (lbs)	SRP (lbs)	TP (lbs)	TSS (lbs)	Fine Sed <20 um (lbs)
BMP1 Type: Detention Basin ==>						*Effluent Quality for BMP Type ==>*		
Total To BMP1		10.73	4.3	59.9	1.6	29.3	14847	9113
BMP1 Bypass	BMP2	0.81	0.3	4.5	0.1	2.2	1116	685
BMP1 Inflow		9.93	4.0	55.4	1.5	27.1	13732	8429
BMP1 Tmnt Assoc. w/ Volume Loss		1.11	0.4	6.2	0.2	3.0	1531	939
BMP1 After Loss		8.82	3.6	49.2	1.3	24.0	12201	7489
BMP1 Treated Out	BMP3	8.82	3.6	36.0	1.3	7.0	4470	4470
BMP1 % Reduction		10%	10%	32%	10%	69%	62%	43%
Total Effluent (incl. Bypass)		9.63	3.9	40.5	1.5	9.2	5586.0	5155
BMP2 Type: Detention Basin ==>						*Effluent Quality for BMP Type ==>*		
Total To BMP2		0.81	0.3	4.5	0.1	2.2	1116	685
BMP2 Bypass	Outlet	0.68	0.3	3.8	0.1	1.9	947	581
BMP2 Inflow		0.12	0.0	0.7	0.0	0.3	168	103
BMP2 Tmnt Assoc. w/ Volume Loss		0.00	0.0	0.0	0.0	0.0	0	0
BMP 2 After Loss		0.12	0.0	0.7	0.0	0.3	168	103
BMP2 Treated Out	BMP3	0.12	0.0	0.5	0.0	0.1	68	68
BMP2 % Reduction		0%	0%	4%	0%	11%	9%	5%
BMP1&2 % Reduction		10%	10%	33%	10%	70%	63%	44%
Total Effluent (incl. Bypass)		9.63	3.9	40.3	1.5	8.9	5486	5120
BMP3 Type: Biofiltration Swale/Strip =======================================>						*Effluent Quality for BMP Type ==>*		
From BMP1		8.82	3.6	0.5	1.3	7.0	4470	4470
From BMP2		0.12	0.0	0.5	0.0	0.1	68	68
Totol To BMP3		8.94	3.6	0.0	1.4	7.1	4538	4538
BMP3 Bypass		0.89	0.4	0.4	0.1	0.7	454	454
BMP3 Inflow		8.05	3.3	0.0	1.2	6.3	4084	4084
BMP3 Tmnt Assoc. w/ Volume Loss		0.12	0.0	0.4	0.0	0.1	61	61
BMP3 After Loss		7.93	3.2	0.4	1.2	6.3	4023	4023
BMP3 Treated Out		7.93	3.2	0.4	1.1	1.1	2308	2308
Treatment Train Effluent		7.93	3.2	0.4	1.1	1.1	2308	2308
Total Bypass Effluent		1.58	0.6	3.9	0.2	2.6	1401	1036
Ultimate Effluent		9.51	3.8	4.3	1.3	3.6	3710	3344
Total Reduction		1.23	0.5	55.6	0.3	25.6	11138	5770
Total Reduction (%)		11%	11%	93%	20%	88%	75%	63%

Figure A.17 – Output2 Load_Red Worksheet

A.4 SWMM Input and Output Worksheets

In addition to the standard worksheets described above, two hidden worksheets containing SWMM input and output are available for review. These worksheets are hidden by default because they are not meant for modification. A more advanced user with detailed knowledge of SWMM may wish to view these worksheets as described below.

A.4.1 SWMM_Input (hidden)

To unhide the worksheet, select **Format** > **Sheet** > **Unhide** from the Excel menu. This worksheet contains input parameters used to create input files for running the Runoff and Storage Treatment Blocks of SWMM. The Runoff Block input files have the form: Runoff[MET Grid No].in (e.g., Runoff88.in) and are located in the folder **RuIn** in the PLRE-STS directory (Figure

A.1). The Storage Treatment Block input files have the form St[MET Grid No].in (e.g., St88.in) and are located in the folder **RuOut** in the PLRE-STS directory (Figure A.1). Input files may be viewed directly using any text file editor program (e.g., Notepad or WordPad). All parameters on this worksheet are either default and should not be changed or are calculated by formula by referencing values in the **Input1 Hydrology** and **Lookup1 Hydrology**.

A.4.2 SWMM_Output (hidden)

To unhide the worksheet, select **Format** > **Sheet** > **Unhide** from the Excel template. This worksheet contains summary output from Runoff and Storage Treatment Blocks. The Runoff Block output files have the form Runoff[MET Grid No].out (e.g., Runoff88.out) and are located in a folder named **RuOut** in the PLRE-STS directory (Figure A.1). Storage Treatment Block output files have the form: St[MET Grid No].out (e.g., St88.out), which are located in a folder named **StOut** in the PLRE-STS directory (Figure A.1). These output files may be viewed directly using any text file editor program (e.g., Notepad or WordPad).

All parameters on this worksheet are either default and should not be changed or are calculated by formula by referencing values in the **Input1 Hydrology** and **Lookup1 Hydrology**.

A.5 Input Data Description

The PLRE-STS requires user defined inputs for project area characteristics and proposed water quality improvements. Input data needs for the PLRE-STS are described in this section in the following format, 1) data the user must supply, 2) data that is user selected based on a range provided by PLRE-STS, and 3) data provided as defaults in the PLRE-STS.

Tables A-1 and A-2 display PLRE-STS data needs the user must supply for hydrology and water quality, respectively. The tables are organized in columns corresponding to the type of data, possible sources for data collection, and the associated input table in the PLRE-STS. The PLRE-STS structure and data needs have been developed to be practical for a user with a basic understanding of hydrology and water quality to implement. The majority of data that a user must supply is typically collected during the project design phase, such as the Formulating and Evaluating Alternatives (FEA) process recommended by the Storm Water Quality Improvement Committee (SWQIC).

Table A.1 - User Supplied Input Data – Catchment and BMP Hydrology

User Supplied Input Data	Potential Source(s)	Table in PLRE-STS
Elevation and average slope	Topographic maps	Table H4: General Catchment Information
Impervious area - directly and indirectly connected	Aerial photography; field survey; GIS layer of impervious cover (DRI/TRPA)	Table H4: General Catchment Information
Pervious area	Aerial photography; field survey	Table H4: General Catchment Information
Subarea routing to pervious conveyance	Field survey	Table H4: General Catchment Information
Representative pervious conveyance length and slope	Field survey	Table H4: General Catchment Information
Pervious conveyance loss rate	Monitoring; soil survey	Table H4: General Catchment Information
Pervious area soil composition	Soil survey, In-situ soil testing	Table H5: Pervious Area Soils
Pervious area vegetation coverage and type	Tahoe Basin Existing Vegetation Map (TBEVM v 4.1); Field survey	Table H6: Pervious Area Vegetation
BMP loss rate	User defined design information	Table H7: BMP Routing and Loss Characteristics
BMP water quality design flow rate	User defined design information	Table H7: BMP Routing and Loss Characteristics
BMP length to width ratio	User defined design information	Table H7: BMP Routing and Loss Characteristics
BMP characteristic footprint area	User defined design information	Table H7: BMP Routing and Loss Characteristics
BMP water quality design volume	User defined design information	Table H7: BMP Routing and Loss Characteristics
BMP water quality design depth	User defined design information	Table H7: BMP Routing and Loss Characteristics
BMP wet pool volume	User defined design information	Table H7: BMP Routing and Loss Characteristics
User defined BMP stage-discharge relationship	User defined design information	Table H8-1: BMP 1 User-Supplied Stage-Discharge

Table A.2 - User Supplied Input Data – Pollutant Load Generation and Reduction

User Supplied Input Data	Potential Source(s)	Table in PLRE-STS
Land use category size relative to total catchment size	TMDL GIS layer; Field survey; GIS layer of impervious cover (DRI/TRPA)	Table Q1: Spatially Distributed Source Accounting - Landuse Based
Average percent impervious for each landuse category	Aerial photography; field survey; GIS layer of impervious cover (DRI/TRPA)	Table Q1: Spatially Distributed Source Accounting - Landuse Based
Total area of road sand application within catchment; recovery rate specified as an annual percentage of road sand applied	Maintenance efficiency reports; implementer knowledge	Table Q3: Specific Source Accounting - Road Sanding
Total area of disturbed surface erosion	Field survey	Table Q4: Specific Source Accounting - Surficial Erosion from Disturbed Areas
Average annual percent delivery of surface erosion to drainage system and/or outfall	Best professional judgment	Table Q4: Specific Source Accounting - Surficial Erosion from Disturbed Areas
Overland flow length of surface erosion and average slope	Field survey; topographic maps	Table Q4: Specific Source Accounting - Surficial Erosion from Disturbed Areas
Soil erodibility factor (K)	Soil survey	Table Q4: Specific Source Accounting - Surficial Erosion from Disturbed Areas
Average annual advancement of gully erosion	Field survey; historical aerial photography; best professional judgment	Table Q5: Specific Source Accounting - Gully Erosion
Average annual percent delivery of gully erosion to drainage system and/or outfall	Best professional judgment	Table Q5: Specific Source Accounting - Gully Erosion
Average length, width, and depth of gully	Field survey	Table Q5: Specific Source Accounting - Gully Erosion

Tables A-3 and A-4 display PLRE-STS data needs the user may select based on PLRE-STS supplied options for hydrology and water quality, respectively. The tables are organized in columns corresponding to the type of data, options for selection, and the associated input table in the PLRE-STS.

Table A.3 - User Selected Input Data – Catchment and BMP Hydrology

User Selected Input Data	Options	Table in PLRE-STS
Simulation duration	Maximum duration is 1970 to 2000	Table H4: General Catchment Information
Output specification	Simulation engines provided - SWMM runoff block, SWMM storage-treatment block, flow duration statistics	Table H3: Output Specifications
Location within Tahoe Basin	MM5 map provided - 142 unique grid cells	Table H4: General Catchment Information
Primary Pervious Conveyance Category	Grass lined, rocky ditch, and natural stream options provided	Table H4: General Catchment Information
Pervious soils method for calculating losses	Texture class or hydrologic soil group options provided	Table H5: Pervious Area Soils
BMP hydraulics	Simulate either a volume-based or flow-based treatment BMP	Table H7: BMP Routing and Loss Characteristics
Flow routing to downstream BMP	Route treated runoff and bypassed runoff to a downstream BMP or to the outfall	Table H7: BMP Routing and Loss Characteristics
BMP stage-discharge relationship	Default stage-discharge curve provided	Table H7: BMP Routing and Loss Characteristics
Draw down time	24, 48, 36, 72 hours currently allowed	Table H7: BMP Routing and Loss Characteristics

Table A.4 - User Selected Input Data – Pollutant Load Generation and Reduction

User Supplied Input Data	Potential Source(s)	Table in PLRE-STS
Land use category size relative to total catchment size	TMDL GIS layer; Field survey; GIS layer of impervious cover (DRI/TRPA)	Table Q1: Spatially Distributed Source Accounting - Landuse Based
Average percent impervious for each landuse category	Aerial photography; field survey; GIS layer of impervious cover (DRI/TRPA)	Table Q1: Spatially Distributed Source Accounting - Landuse Based
Total area of road sand application within catchment; recovery rate specified as an annual percentage of road sand applied	Maintenance efficiency reports; implementer knowledge	Table Q3: Specific Source Accounting - Road Sanding
Total area of disturbed surface erosion	Field survey	Table Q4: Specific Source Accounting - Surficial Erosion from Disturbed Areas
Average annual percent delivery of surface erosion to drainage system and/or outfall	Best professional judgment	Table Q4: Specific Source Accounting - Surficial Erosion from Disturbed Areas
Overland flow length of surface erosion and average slope	Field survey; topographic maps	Table Q4: Specific Source Accounting - Surficial Erosion from Disturbed Areas
Soil erodibility factor (K)	Soil survey	Table Q4: Specific Source Accounting - Surficial Erosion from Disturbed Areas
Average annual advancement of gully erosion	Field survey; historical aerial photography; best professional judgment	Table Q5: Specific Source Accounting - Gully Erosion
Average annual percent delivery of gully erosion to drainage system and/or outfall	Best professional judgment	Table Q5: Specific Source Accounting - Gully Erosion
Average length, width, and depth of gully	Field survey	Table Q5: Specific Source Accounting - Gully Erosion

Tables A-5 and A-6 display PLRE-STS data needs based on default lookup values for hydrology and water quality, respectively. The tables are organized in columns corresponding to the type of data, description of data, and the associated input table in the PLRE-STS. The default lookup values are not recommended for modification unless a project proponent can demonstrate that the default values do not adequately represent a project area. If a project proponent has sufficient monitoring data, specific to a project area or a BMP, they may be justified in modifying the default values.

Table A.5 - Lookup Data – Catchment and BMP Hydrology

Lookup Data	Description of Data	Table in PLRE-STS
General hydrologic constants	Default values used in the SWMM engine including the wet and dry time steps	Table LH00: General Constants
Soil properties used to compute losses	Default values referenced to soil texture and hydrologic soil group used in the Green-Ampt loss method	Table LH3: Soils Properties
Vegetation properties	Default values referenced to vegetation type used to compute initial abstraction	Table LH4: Landscape Coefficient Factors
Vegetation cover properties	Default values referenced to vegetation cover to compute depression storage and a snowmelt coefficient	Table LH5: Vegetative Cover
Evapotranspiration	Default monthly values for computing evapotranspiration	Table LH6: Monthly Evapotranspiration Values
Pervious conveyance routing	Default Manning's n for rock-lined, grass-lined, and natural stream conveyance	Table LH8: Stormwater Conveyance
BMP particle settling	Default values to compute particle settling for various size ranges of fine particles	Table LH10: Particle Settling

Table A.6 - Lookup Data – Pollutant Load Generation and Reduction

Lookup Data	Description of Data	Table in PLRE-STS
Land use category concentrations for priority pollutants	Median EMCs from TMDL data for TSS, dissolved and total phosphorous, dissolved and total nitrogen, and fine sediment as a ratio to TSS	Table LQ1: Median EMCs by Landuse Category
Land use condition crediting	Relates area under a normal distribution to the percent reduction in EMC based on landuse condition	Table LQ5: Z-Values and % Reduction in EMCs for Landuse Source Accounting
Road sanding application rate	Low, medium, and high application rates represent 25, 50, and 75th percentile of 2005 Caltrans data distribution	Table LQ6: Specific Source Loading Rates - Road Sanding
Road sand and Tahoe soils chemical composition	Priority pollutants represented as a percentage of sediment present for specific source control accounting	Table LQ7: Tahoe Soils and Road Sand Composition
USLE rainfall energy factor	Rainfall energy factor = 10 for Tahoe Basin (future refinement needed to consider elevation and orographic effects)	Table LQ9: Specific Source Lookup Reference - Disturbed Area (USLE basis)
Soil composition for disturbed areas	Relates USLE cover management factor to description of soil composition	Table LQ10: C Factors
Vegetative cover present on disturbed area	Refines USLE cover management factor based on vegetative cover	Table LQ11: Percent Surface Cover
BMP effluent quality	Median effluent quality for selected treatment BMPs available - current data is from national database	Table LQ14: BMP Effluent Quality (mg/L)

Methodology to Estimate Pollutant Load Reductions

Appendix B – Examples and Discussion of PLRE-STS Output

Final Report

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Table of Contents

List of Tables

List of Figures

B.1 Example 1 – Pilot Application of the PLRE-STS

The purpose of this example is to compare the predicted existing condition pollutant loading to the feasible reduction in pollutant loading after implementation of source controls and storm water treatment BMPs. Three simulations were developed for this example: 1) Brockway Existing Conditions Pollutant Load, 2) Brockway Source Control Implementation, and 3) Brockway Storm Water Treatment Implementation.

B.1.1 Background

The following example is based on the Brockway Erosion Control Project, located on the North Shore of Lake Tahoe, approximately at the state line between California and Nevada. Input data for the existing conditions simulation was derived from information contained in the Brockway Existing Conditions Memorandum (Placer County, 2005). Alternatives illustrating source control implementation and treatment options are hypothetical and are not based on potential alternatives for the Brockway Erosion Control Project.

The Brockway existing conditions memorandum contains five delineated catchments, totaling roughly 127 acres. A single catchment, referenced as B4 in the Brockway existing conditions memorandum was selected for this analysis due to its mixture of land use and specific sources of pollutant loading. The reader is reminded that the current version of the PLRE-STS can only simulate a single catchment.

B.1.2 Brockway Existing Conditions Pollutant Load

The selected catchment is 27 acres in size with a mix of land uses including Highway, Commercial, Single Family Residential, and Moderately Disturbed Open Space. Total impervious area is roughly 35 percent of the selected catchment with about 2/3 of the impervious area considered directly connected. Soils are approximated as hydrologic soil group C for the catchment area. Vegetation is a mix of herbaceous, shrub, and open coniferous canopy. Figure B.1 displays the catchment characteristic input data assumed for the existing conditions analysis.

Minimal BMPs and source controls are present in the existing condition. Specific sources of pollutants added to the simulation include two dirt roads, moderate residential road sanding, and an eroding gully.

Table H4: General Catchment Information:		
MM5 MET Grid ID	120	**Sub Area Routing** 0 - Direct to Outlet (or BMP Treatment Train) 1 - Pervious Conveyance
Elevation (ft)	6300	
Average Catchment Slope (%)	8.5	
Directly Connected Impervious Area **[A]** (acres)	6.25	1
Disconnected Impervious Area **[B]** (acres)	3.25	Area C
Total Imperviousness Area (acres)	9.5	
Perv Area Receiving Imperv Runoff **[C]** (acres)	4.5	1
Perv Area Not Receiving Runoff **[D]** (acres)	13.3	1
Total Pervious Area (acres)	17.8	
Catchment Area (acres)	27.3	
Representative Pervious Conveyance Length (ft)	1500	
Primary Conveyance Slope (%)	8.5	
Primary Conveyance Saturated Loss Rate (in/hr)	0.15	

Figure B.1 – Catchment Input Data for Existing Condition

Pollutant load generation output from the existing condition simulation is presented in Figure B.2. On an average annual basis the PLRE-STS is predicting 5.32 acre-feet of runoff from the 27.3 acre catchment. Suspended sediment loads are fairly similar for the distributed pollutant source accounting (land use) and specific pollutant source accounting techniques. The distributed pollutant sources contribute the majority of pollutant loading for nutrients, according to the PLRE-STS simulation.

Table OLG4: Summary of Average Annual Loads From All Sources								
	Annual Average Runoff		Total Pollutant Loads to BMP1 Including Specific Sources					
Land Use	% Runoff	Runoff Volume (ac-ft)	O3-N (lbs	TKN (lbs)	SRP (lbs)	TP (lbs)	TSS (lbs)	Fine Sed <20 um (lbs)
Total Load from Land Uses		5.32	33	4	11	2	3,872	2,341
Total Load from Specific Sources			0	3	0	2	3,355	1,343
TOTAL RUNOFF LOADS	21.2%	5.32	33	7	11	3	7,228	3,684

Figure B.2 – Pollutant Load Generation Output for Existing Condition

B.1.3 Brockway Source Control Implementation

This example expands on the **Brockway Existing Conditions Pollutant Load** example by assuming implementation of hypothetical hydrologic and pollutant source controls. Storm water treatment BMPs are not included in the example. The purpose of this example is to estimate the water quality benefit realized from hydrologic and pollutant source control implementation. The following hydrologic and pollutant source control improvements were added to the model:

Hydrologic Source Controls

1. Pervious area receiving impervious runoff was increased by 60%.
2. Directly connected impervious area was decreased by 20%
3. Primary conveyance channel infiltration was improved by 100%.
4. Non-vegetated areas were decreased by 20% with a commensurate 10% increase in both herbaceous and shrub vegetation.

Spatially Distributed Pollutant Source Controls

1. *Single Family Residential* conveyance system improved to Tier 2, road shoulder stabilization improved to Tier 2, and BMP maintenance improved to Tier1.
2. *Commercial (CICU)* conveyance system improved to Tier 1 and BMP maintenance improved to Tier 2.
3. *Primary Road (Highway)* BMP maintenance improved to Tier 1.

Note – see Section 7 of the main report for a description of Tiers.

Specific Pollutant Source Controls

1. Both unpaved roads were stabilized.
2. Gully erosion was mitigated to less than 0.5 feet per year of propagation.
3. Moderate road sanding recovery was increased from 40% to 80%.

Pollutant load generation output from the existing condition simulation is presented in Figure B.2, which can be compared to output in Figure B.3 to review decreases in the pollutant load generated between simulations. The simulated hydrologic source controls reduced the average annual runoff from 5.32 acre-feet for the existing condition simulation to 3.90 acre-feet for the hydrologic source control simulation. This equates to roughly a 27% reduction in runoff volume on an average annual basis due to reductions in impervious area and impervious connectivity, as well as increases in infiltration rates and vegetative cover. This type of analysis may prove useful for estimating the maximum feasible runoff volume reduction for project alternatives.

Table OLG4: Summary of Average Annual Loads From All Sources

	Annual Average Runoff		Total Pollutant Loads to BMP1 Including Specific Sources					
Land Use	**% Runoff**	**Runoff Volume (ac-ft)**	**O3-N (lbs**	**TKN (lbs)**	**SRP (lbs)**	**TP (lbs)**	**TSS (lbs)**	**Fine Sed <20 um (lbs)**
Total Load from Land Uses		3.90	19	2	6	1	2,348	1,431
Total Load from Specific Sources			0	1	0	1	926	390
TOTAL RUNOFF LOADS	15.6%	3.90	19	3	6	1	3,274	1,822

Figure B.3 – Pollutant Load Generation Output after Source Controls

The combination of runoff volume reduction and the implementation of spatially distributed pollutant source controls reduced the average annual pollutant loading by roughly 27% for the spatially distributed pollutant source technique. The assumptions for implementation of specific pollutant source controls reduced the average annual pollutant loading by roughly 72% for the specific pollutant source technique. This reduction is likely high because the disturbed areas present in the existing condition were assumed to be fully mitigated and the eroding gully present in the existing condition was assumed to be significantly mitigated. Guidance regarding the assumptions a user should make to quantify the water quality benefit of a specific pollutant source control is limited and recognized as an area of needed improvement for the next version of the PLRE-STS.

B.1.4 Brockway Storm Water Treatment Implementation

This example expands on the **Brockway Source Control Implementation** example and could be considered the storm water treatment alternative after implementation of hydrologic and pollutant source controls. The following storm water treatment BMPs are modeled in series at the outfall of the simulated catchment: detention basin, to an infiltration gallery, to a vegetated swale. Due to lack of BMP performance data for infiltration galleries, this BMP is simulated as a detention basin with a high loss rate. The purpose of this example is to predict the load reduction realized from implementation of storm water treatment BMPs after hydrologic and pollutant source controls have been implemented. Figure B.4 displays the input data used in the PLRE-STS to simulate the three BMPs.

Table H7: BMP Routing and Loss Characteristics			
General Data:			
Storage-Treatment Time Step (min)	10	<= Default value change only in Lookup Hydrology Table LH00	
		Upstream to Downstream →	
Treatment Train Configuration:	**BMP1**	**BMP2**	**BMP3**
BMPs Simulated	Yes	Yes	Yes
BMP Type	Detention Basin	Detention Basin	Wetland Basin or Channel
BMP Hydraulics	Volume-Based	Volume-Based	Flow-Based
Bypass flow routed to	BMP2	BMP3	Outlet
Treated flow routed to	BMP2	Outlet	Outlet
BMP Loss Rate (in/hr)	0.05	0.75	0.1
WQ Design Flow Rate, Q_{design} (cfs)	0	0	1
Length to width ratio	2	3	10
Additional Parameter Required for Flow-Based BMPs			
Characteristic Footprint Area (sf)	0	0	1000
Additional Parameters Required for Volume-Based BMPs			
Water Quality Design Volume (cu-ft)	11000	5000	0
Permanent Wet Pool Volume (cu-ft)	0	0	0
Permanent Wet Pool Depth (ft)	0	0	0
WQ Design Depth (live storage) (ft)	2	3	0
Total Basin Depth (ft)	3.5	3	0
BMP Stage-Discharge	Default	Default	Default
Brim-Full Draw Down Time (hours)	72	48	24

Figure B.4 – Treatment BMPs Input Data

General characteristics of each of the three BMPs simulated are as follows.

Detention Basin (BMP 1)

1. 0.25 acre-feet of storage
2. Loss rate 0.05 inches per hour
3. Depth 2 feet; length to width 2:1
4. Bypassed and treated flow is routed to the infiltration gallery.

Infiltration Gallery (BMP2)
1. The infiltration gallery is simulated as a detention basin with a high infiltration rate.
2. 0.1 acre-feet of storage
3. Loss rate 0.75 inches per hour
4. Bypassed flow is routed to the vegetated swale; treated flow is routed to the outlet.

Vegetated Swale (BMP3)
1. 1 cfs water quality design flow rate
2. Loss rate 0.1 inches per hour
3. 1000 ft^2 for the characteristic footprint area

Figure B.5 displays the load reduction output for the overall treatment train implemented. Additional output regarding the load reduction of each BMP is contained in the PLRE-STS output, but not shown in this abbreviated example.

Table OLR1: Average Annual Influent and Effluent Loads and Concentrations from Centralized BMPs

	Runoff		Pollutant Loads from All Sources					
	Routing	Runoff Volume (ac-ft)	NO3-N (lbs)	TKN (lbs)	SRP (lbs)	TP (lbs)	TSS (lbs)	Fine Sed <20 um (lbs)
Treatment Train Effluent		1.38	1.8	1.1	0.2	0.5	385	385
Total Bypass Effluent		1.17	4.4	0.9	1.3	0.4	740	460
Ultimate Effluent		2.55	6.2	1.9	1.5	0.9	1125	845
Total Reduction		1.36	12.6	1.0	4.8	0.5	2149	976
Total Reduction (%)		35%	67%	35%	76%	35%	66%	54%

Figure B.5 – Treatment BMPs Output for Load Reduction

The treatment train of BMPs (detention basin to infiltration gallery to wetland channel) reduced the total pollutant loading for TSS by 66% relative to influent loads that included implementation of hydrologic and pollutant source controls. Final pollutant loading was approximately 1,125 pounds of TSS per year. The existing condition pollutant loading for TSS was simulated at 7,228 lbs per year, which translates to approximately an 84% load reduction per year if hydrologic and pollutant source controls and storm water treatment BMPs were implemented.

Nutrient pollutant reduction simulated for the treatment train performed poorly. This may be due to the use of the International BMP database effluent data instead of Tahoe specific values and the fact that nutrients, particularly dissolved nutrients, are difficult to remove with conventional BMPs. A future refinement to the model using Tahoe specific monitoring data may significantly improve results for nutrients. Sizing facilities to minimize bypass flows, or designing systems that capture bypassed flows downstream greatly increases the treatment efficiency of the system as a whole.

B.2 Example 2 – Simulated Loading Compared to Monitored Estimate of Loading

The purpose of this example is to compare simulated output from the PLRE-STS to estimates of pollutant loading and pollutant load reduction derived from monitoring data for the Coon Street Detention Basin, located in Kings Beach, CA.

B.2.1 Monitored Pollutant Loads

The Kings Beach Watershed Improvement Project is located in Kings Beach on the North Shore of Lake Tahoe. Previous erosion control projects have constructed various water quality improvements including detention basins. Among the detention basins constructed is the Coon Street Detention Basin located on the corner of Coon and Trout Streets, north of SR 28.

The Tahoe Environmental Research Center (TERC) monitored the Coon Street Detention Basin during water years 2003 and 2004. The draft report produced from this monitoring effort (Heyvaert 2005) includes an estimate of pollutant loading and total runoff volume at the inlet and outlet of the Coon Street Detention Basin for water year 2004. The outlet data for water year 2004 is believed to provide a fairly accurate estimate of total load and runoff volume leaving the detention basin. The inlet data is considered less accurate due to sampling difficulties caused by backwater conditions. The annual load and runoff volume for the inlet was calibrated based on selected events and the outlet data. The data provides a reasonable estimate of annual pollutant loading from an urban drainage area, as well as a reasonable estimate of annual pollutant load reduction by a detention basin. Table B.1 displays the annual loads for the influent and effluent storm water at the Coon Street Detention Basin for water year 2004.

Table B.1 - Estimated Annual Loads for WY04 (Heyvaert 2005)

	TN	TKN	NO3-N	NH4-N	TP	TDP	SRP	TSS	Volume
Site	**(lbs)**	**(lbs)**	**(lbs)**	**(lbs)**	**(lbs)**	**(lbs)**	**(lbs)**	**(lbs)**	**(cf)**
Coon Basin In	98.8	71.9	26.7	4.4	27.3	4.2	3.7	6394.5	505,016
Coon Basin Out	41.2	34.2	7.1	1.8	7.9	2.9	2.2	882.0	464,273

B.2.2 Simulated Pollutant Loads

Input data for the PLRE-STS simulation was derived from information contained in the TERC monitoring report and the Kings Beach Hydrologic Conditions Report (Entrix 2005). The PLRE-STS simulates pollutant loading to the Coon Street Detention Basin, as well as, basin performance for pollutant load reductions. Simulated output from the PLRE-STS was compared to the estimated loads derived from monitoring data (Table B.1).

The majority of input data for hydrology and pollutant load generation was derived from the Entrix report, including estimates of impervious area, MM5 grid location, impervious connectivity, soils, and landuse. Figure B.6 displays general catchment characteristics that were estimated and used as input to the PLRE-STS. The TERC and Entrix reports differ regarding the estimated drainage area to the Coon Basin. The PLRE-STS simulation uses the Entrix estimate (56 acres) because it provided runoff results close to the monitoring estimate. The correct drainage area should be verified. If the drainage area is closer to the TERC estimate, which is smaller, the modeling assumptions regarding infiltration and directly connected impervious area should be reviewed.

Table H4: General Catchment Information:		
MM5 MET Grid ID	127	Sub Area Routing 0 - Direct to Outlet (or BMP Treatment Train) 1 - Pervious Conveyance
Elevation (ft)	6360	
Average Catchment Slope (%)	7	
Directly Connected Impervious Area **[A]** (acres)	9	0
Disconnected Impervious Area **[B]** (acres)	11	Area C
Total Imperviousness Area (acres)	20	
Perv Area Receiving Imperv Runoff **[C]** (acres)	10.5	1
Perv Area Not Receiving Runoff **[D]** (acres)	25.5	1
Total Pervious Area (acres)	36	
Catchment Area (acres)	56.0	
Representative Pervious Conveyance Length (ft)	2000	
Primary Conveyance Slope (%)	7	
Primary Conveyance Saturated Loss Rate (in/hr)	0.05	

Figure B.6 – Catchment Characteristic Input Data

Landuse distribution for the spatially distributed pollutant source accounting technique was simulated as: 53% Single Family Residential, 31% Multi Family Residential, 14% Moderately Disturbed Open Space, and 2% Commercial. Specific pollutant source accounting was used to simulate potential road sanding activities and disturbed areas, referenced in the Entrix report.

The Coon Street Detention Basin hydraulic design information was taken from Heyvaert (2005), which included a basin survey performed by TERC, which providing accurate information for detention basin volume and basin depth relative to surface area. This information allowed for development of a user-defined stage discharge relationship. Figure B.7 displays the hydraulic design parameters input into the PLRE-STS. In Figure B.7, the Coon Street Detention Basin is simulated as “BMP1.”

Table H7: BMP Routing and Loss Characteristics			
General Data:			
Storage-Treatment Time Step (min)	10	<= Default value change only in Lookup Hydrology Table LH00	
		Upstream to Downstream →	
Treatment Train Configuration:	**BMP1**	**BMP2**	**BMP3**
BMPs Simulated	Yes	No	No
BMP Type	Detention Basin	Detention Basin	Biofiltration Swale/Strip
BMP Hydraulics	Volume-Based	Volume-Based	Flow-Based
Bypass flow routed to	Outlet	Outlet	Outlet
Treated flow routed to	Outlet	Outlet	Outlet
BMP Loss Rate (in/hr)	0.1	0	0
WQ Design Flow Rate, Q_{design} (cfs)	0	0	0
Length to width ratio	1.5	1	1
Additional Parameter Required for Flow-Based BMPs			
Characteristic Footprint Area (sf)	0	0	10000
Additional Parameters Required for Volume-Based BMPs			
Water Quality Design Volume (cu-ft)	20400	2000	0
Permanent Wet Pool Volume (cu-ft)	0	0	0
Permanent Wet Pool Depth (ft)	0	0	0
WQ Design Depth (live storage) (ft)	3.5	4	0
Total Basin Depth (ft)	3.5	4	0
BMP Stage-Discharge	User-Supplied	Default	Default
Brim-Full Draw Down Time (hours)	24	36	24

Figure B.7 – Hydraulic Design Input Data for the Detention Basin

B.2.3 Comparison of Simulated and Monitored Load Estimates

Hydrology

Figure B.8 displays general hydrologic output from the PLRE-STS. Over the 30 year simulation the average annual precipitation using the MM5 meteorological data was 11.65 inches. This value appears too low for an average annual value in Kings Beach[1], but compares well to the measured precipitation of 10.4 inches for water year 2004. Simulated average annual runoff to the Coon Street Detention Basin was 10.73 acre-feet (467,400 ft^3) compared to the monitoring estimated of 11.6 acre-feet (505,000 ft^3). The percentage of average annual simulated rainfall to measured rainfall for water year 2004 is 112% and the percentage of average annual simulated runoff to measured runoff for water year 2004 is 93%. The results indicate that the PLRE-STS is providing a fairly close estimate of runoff, given that the simulated average annual precipitation and the measured precipitation were similar. The simulated output does report a higher average precipitation but a lower average runoff. It is likely that either the size of the drainage area

[1] As discussed in Section 8.3 of the main report, the MM5 data set currently under predicts rainfall in the Tahoe Basin. MM5 recalibration is a high priority refinement noted by the TMDL program.

simulated or the relative amount of impervious area simulated may be slightly less than actual conditions.

Table OH1: Hydrologic Continuity Results			
Parameter	Total Period of Record (ac-ft)	Average Annual (ac-ft)	Average Annual (inches)
Total Rain&Snow	1631.63	54.39	11.65
Rain Only	842.00	28.07	6.01
Snow Only (water equivalent)	789.64	26.32	5.64
Water Remaining in Surface Storage	0.00	0.00	0.00
Water Remaining in Snow	0.00	0.00	0.00
Total Loss Due to Infiltration	1072.89	35.76	7.66
Total Loss Due to Evapotranspiration	158.76	5.29	1.13
Total Runoff Volume	321.85	10.73	2.30
Percent Runoff (%)	0.20	19.7%	19.7%

Figure B.8 – Simulated Hydrology Output

Pollutant Load Generation

The measured pollutant loads at the inlet to the Coon Basin were much larger than the simulated pollutant loads generated by the spatially distributed pollutant source accounting technique. Figure B.9 displays the simulated pollutant load generation, which can be compared to the "Coon Basin In" row of Table B.1. Given that annual runoff volumes were fairly similar for the monitored and simulated output, it appears that for this drainage area the spatially distributed pollutant source accounting technique would result in an under prediction of pollutant load generation if specific pollutant sources were not included. This finding may help support the idea that in order to reasonably predict pollutant load generation from some project areas, a combined use of the distributed and specific pollutant source accounting methods is warranted.

The Coon Street Detention Basin drainage area is fairly steep and likely receives a fair amount of road sanding. Additionally, the Entrix report identified multiple disturbed areas within the drainage catchment. By estimating and adding road sanding and disturbed areas as specific pollutant sources to the PLRE-STS, the total pollutant load generation derived from the simulated output compared reasonably well to the estimated pollutant load derived from monitoring data. Figure B.9 displays average annual pollutant load generation from the distributed pollutant source accounting technique (land use) and the specific pollutant source accounting technique.

Table OLG4: Summary of Average Annual Loads From All Sources								
	Annual Average Runoff		Total Pollutant Loads to BMP1 Including Specific Sources					
Land Use	% Runoff	Runoff Volume (ac-ft)	O3-N (lbs	TKN (lbs)	SRP (lbs)	TP (lbs)	TSS (lbs)	Fine Sed <20 um (lbs)
Total Load from Land Uses		10.73	65	8	15	4	3,104	1,626
Total Load from Specific Sources			0	0	0	1	2,576	1,532
TOTAL RUNOFF LOADS	19.7%	10.73	65	8	15	5	5,680	3,158

Figure B.9 – Simulated Pollutant Load Generation

Pollutant Load Generation

The pollutant load reduction estimated from monitoring data compared reasonably well to the simulated pollutant load reduction of the Coon Street Detention Basin. Figure B.10 displays the simulated pollutant load reduction. Table B.2 displays the monitoring estimate, which is identical to Table B.1, but is included below for easier comparison. In Figure B.10, the row "Total to BMP1" represents simulated influent pollutant loading and in Table B.2 the row "Coon Basin In" is the monitored estimate of influent pollutant loading. In Figure B.10, the row "Total Effluent (incl. Bypass)" represents simulated effluent pollutant loading and in Table B.2 the row "Coon Basin Out" is the monitored estimate of effluent pollutant loading.

Table OLR1: Average Annual Influent and Effluent Loads and Concentrations from Centralized BMPs

	Runoff		Pollutant Loads from All Sources					
	Routing	Runoff Volume (ac-ft)	NO3-N (lbs)	TKN (lbs)	SRP (lbs)	TP (lbs)	TSS (lbs)	Fine Sed <20 um (lbs)
BMP1 Type: Detention Basin ========================>								*Effluent Quality for BMP Type ==>*
Total To BMP1		10.73	64.6	8.0	15.2	4.8	5,680	3,158
BMP1 Bypass	Outlet	0.78	4.7	0.6	1.1	0.3	414	230
BMP1 Inflow		9.95	59.9	7.5	14.1	4.5	5,266	2,928
BMP1 Tmnt Assoc. w/ Volume Loss		1.11	6.7	0.8	1.6	0.5	586	326
BMP1 After Loss		8.84	53.2	6.6	12.5	4.0	4,680	2,603
BMP1 Treated Out	Outlet	8.84	16.3	6.6	1.6	4.0	1,555	1,555
BMP1 % Reduction		10%	67%	10%	82%	10%	65%	43%
Total Effluent (incl. Bypass)		9.62	21.1	7.2	2.7	4.3	1,969	1,785

Figure B.10 – Simulated Pollutant Load Reduction

Table B.2 - Estimated Annual Loads for WY04 (Heyvaert 2005)

Site	TN (lbs)	TKN (lbs)	NO3-N (lbs)	NH4-N (lbs)	TP (lbs)	TDP (lbs)	SRP (lbs)	TSS (lbs)	Volume (cf)
Coon Basin In	98.8	71.9	26.7	4.4	27.3	4.2	3.7	6394.5	505,016
Coon Basin Out	41.2	34.2	7.1	1.8	7.9	2.9	2.2	882.0	464,273

Although the monitored hydrologic losses due to infiltration and evapotranspiration were estimated, the simulated hydrologic losses compared extremely well. Both methods estimate that roughly 10% of the annual volume was lost in the detention basin due to infiltration and evapotranspiration.

The percent removal for TSS compared reasonably well. Estimated reduction in TSS from the monitoring data was higher but the detention basin did not experience bypass flows in water year 2004. The simulation includes bypassed flows over the 30 year period of record, which decreases the average annual efficiency of the detention basin. Additionally, the simulation output assumes the remaining TSS in the effluent load is fine sediment (<20 microns), as shown in the row "BMP Treated Out" where TSS load and fine sediment loads are equal.

Percent removal for nutrients compared poorly. Simulated reduction in pollutant loads was much less than measured reduction. This is likely because the current simulation for detention basins uses International BMP database effluent values. A future refinement to the PLRE-STS that uses Tahoe specific monitoring data may improve load reduction results for nutrients.

B.3 References

Entrix. 2005. Kings Beach Watershed Improvement Project. Administrative Draft Hydrologic Conditions Report. Prepared for Placer County, Truckee, CA.

Heyvaert, A.C., Parra, A. 2005. Performance Assessment of the Coon Street Detention Basin, Kings Beach, CA. Prepared for Placer County, Truckee, CA and the California Tahoe Conservancy, South Lake Tahoe, CA.

Placer County. 2005. Brockway Erosion Control Project Existing Conditions Analysis Memorandum.

Methodology to Estimate Pollutant Load Reductions

Appendix C – Tahoe Interview Summaries

Final Report

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C.1 Interview Process

1. A total of fifteen interviews were conducted with one or more staff members from regulatory/funding agencies, implementing agencies and consulting firms. An interview form was developed and distributed to interviewees prior to the interviews, which were conducted over a two-week period between February 14 and February 25, 2005. The discussions were held in person whenever possible, although several phone interviews were necessary due to time constraints. The interviews lasted from 45 minutes to two hours, depending on the detail of responses. Written responses were provided by five respondents, although virtually all respondents had reviewed the form prior to the interview. The interviewees are listed in Table C.1.

Table C.1: List of Interviewees

Agency Type	Agency/Firm	Personnel Interviewed
Regulators/Funders	California Tahoe Conservancy	Kim Carr Dave Zander Steve Bachmann Brent Wolfe
	Lahontan Regional Water Quality Control Board	Lauri Kemper (written only) Doug Smith Bob Larsen
Implementers	Caltrans	Rich Williams Tom Rutsch
	City of South Lake Tahoe	Stan Hill Russ Wigart
	Douglas County	Ron Roman
	El Dorado County	Steve Kooyman
	Incline Village General Improvement District	Joe Pomroy Ursula Lipkowitz
	Nevada Department of Transportation	Steve Cooke Theresa Jones
	Nevada Tahoe Conservation District	Jason Drew Chad Praul
	Placer County	Peter Kraatz Kansas McGahan
	United States Forest Service	Sue Norman
Consultants	CDM	Blake Johnson Tom Quasebarth
	K.B. Foster	Jim Rienstra
	Lumos & Associates	Chas Macquarie Brian McRae
	MACTEC	Jay Aldean

C.2 Interview Form

An interview form was developed with input from the Project Advisory Committee (PAC) that grouped questions into eight primary topics related to current water quality practices and implementation of the TMDL program. The form was provided to the interviewees prior to the interviews, with a cover letter describing the purpose of the current study. A copy of the form is provided at the end of this appendix. A brief description of the eight categories of questions in the interview form is presented below.

1. BMP Selection
Interviewees were asked to rank the importance of 13 elements related to BMP selection/evaluation by their organization. In addition, they were asked to discuss the five most important elements in greater detail. The purpose of these questions was to establish what factors significantly influence BMP selection within the Tahoe Basin.

2. BMP Design Criteria
A series of questions were posed that addressed BMP design details, such as design flows and volumes, BMP geometries, hydrologic criteria, soils and groundwater criteria and relevant technical references. These questions were intended to highlight commonly used design criteria, as well as identify any innovative approaches currently used in the Basin.

3. BMP Design/Implementation Constraints
Several questions were asked regarding project design constraints as they relate to concentration- or load-based water quality design, utilization of non-passive BMPs (e.g. chemical treatment), and land use. The responses provided insight into commonly-perceived difficulties in BMP design and implementation.

4. Typical Practices
These questions addressed typical BMP selection and design practices. Interviewees were requested to comment on their use of high-flow bypasses and treatment trains, as well as identify which BMPs they had previously selected for implementation one or more times.

5. Regulatory and Performance Standards
The interviewees were questioned about how regulatory and performance standards affect BMP design, including their opinions on the adequacy of these standards and a description of the types of calculations performed to demonstrate compliance. The responses helped identify the most- and least-frequently applied standards.

6. Analytical Tools and Data Sources
This topic covered project information sources, as well as application of hydrologic and water quality design tools. Interviewees were also asked to identify any other tools that might be useful for individual BMP or project design purposes.

7. Maintenance and Monitoring Practices
A group of questions was posed to the interviewees regarding their maintenance and monitoring practices, including type performed, scheduling, and reporting requirements. Questions were also asked about how monitoring results were utilized in BMP design, if at all.

8. Summary
The final section focused on identifying methodologies to estimate project effectiveness with regard to pollutant load reduction during the design phase. Interviewees were asked whether they were aware of any such methodologies being applied inside or outside the Tahoe Basin.

C.3 Observations from Interviews

A tabular compilation of interview responses is provided in the next section. The tables provide a direct record of the responses, without interpretation from the project team. During the course of the interviews, general trends in preferences and opinions about water quality design became apparent and follow-up questions were frequently used in the oral interviews to clarify or elaborate on the responses. This section therefore summarizes observations from the interviews and provides an interpretation of the responses in the context of current practices in the Tahoe Basin. The observations are organized into the eight main topic areas.

1. BMP Selection

   The most important elements in BMP selection were identified as follows:

   - regulators/funders: pollutants of concern
   - implementers: site constraints

   In general, regulators/funders ranked elements related to water quality constituents and regulatory requirements as most important in BMP selection, while implementers and consultants ranked ancillary project elements like drainage/flood control benefits, site constraints, downstream effects, etc. as more important.

   The general trends apparent in the interview results reflect the disparate concerns of the different agencies and firms involved in water quality projects in the Tahoe Basin. Regulators/funders are primarily concerned with ensuring that projects achieve water quality goals. Implementers and consultants, on the other hand, are more engaged in the factors that affect the funding, construction, and maintenance of water quality projects given the constraints of the physical setting and land use conditions.

2. BMP Design Criteria

   The interviewees were asked about criteria they regularly used to design various kinds of water quality BMPs. By far the most common criterion for volumetric design was the runoff from the 20-year 1-hour storm event (1 inch). This was typically applied to the impervious surface within the entire project area, although occasionally it was only applied to the impervious surface within the right-of-way. Some respondents noted that it was difficult to design for this much volume, while others said they often tried to design for even greater volumes when site constraints allowed.

   The 10-year 24-hour storm event was most commonly used for design of conveyance features. Flow-based BMP design criteria included minimum and maximum flow velocities and preferred detention times. Responses were more varied when considering BMP configurations or hydraulic design; many respondents did not utilize any specific criteria, although a few referenced factors such as retention times and particle settling rates.

   The primary hydrologic design storms were the 20-year 1-hour event for volume, the 10-year 24-hour peak flow for conveyance design and the 100-year peak flow for flooding issues. Two main factors were cited in the discussion of soils and groundwater criteria: a minimum separation from the bottom of basins to seasonally high groundwater (ranging from 1 to 10 feet), and review/testing of in situ infiltration rates. Finally, a list of technical references was developed from the respondents, but many said that project experience was much more valuable than any technical reference they could identify.

3. BMP Design/Implementation Constraints
Respondents had no difficulty in cataloging an extensive list of constraints related to BMP design/implementation. The primary constraints identified in relation to designing projects based on water quality treatment performance were cost, lack of information on pollutant loadings and BMP efficiencies, and problems with location and availability of adequate land for construction.

   Similar constraints were reported for design of non-passive BMPs, with additional concerns about the technical challenges involved, the potential for harmful effluent constituents from chemically-based systems, and operations and maintenance requirements. General resistance from project implementers to these types of BMPs was also cited as a significant constraint. This resistance likely stems from a feeling that these types of BMPs are not feasible to operate and maintain; one implementer noted that non-passive treatment systems are usually the “throw-away” alternative when planning a storm water quality improvement project.

   Finally, constraints associated with property and land-use were listed primarily as a lack of undeveloped land available in strategic locations for water quality projects, high costs, limited right-of-way, and physical constraints such as steep land and location of stream environment zones (SEZs). Many respondents noted that these constraints often drove individual BMP selection and overall project design.

4. Typical Practices
The first question posed regarding typical practices asked about preferences regarding under- and aboveground BMPs. A little less than half the respondents stated that they generally had no preference, and that this decision was typically driven by site constraints and BMP effectiveness. The remaining respondents noted the benefits and disbenefits of both types of BMPs, with an apparent preference for aboveground BMPs because of ease of construction, monitoring and maintenance as well as perceived higher treatment effectiveness. Some respondents like underground BMPs because they prove useful in treatment trains and work better in urbanized areas.

   The vast majority of respondents have specified or recommended treatment trains in the course of their work. Most felt that they provide a higher level of treatment and help in meeting regulatory requirements. Space constraints may either limit or drive their implementation, and they may range from very simple vault pre-treatment systems to more advanced three- or four-facility systems.

   Interviewees were presented with a list of 18 typical BMPs and asked to comment on whether they had used each of these BMPs one or more times. The most commonly implemented BMPs were source control, dry detention basins, bioswales, sump sediment traps, passive hydraulic sediment traps (e.g. double-barreled sand traps) and oil and grease traps. Respondents noted that BMP selection was affected by many factors, including cost and site constraints, past project experience, required level of maintenance and the regulatory review process. Many interviewees were aware of the benefits of designing a high flow bypass for their water quality BMPs, and while many tried to incorporate this feature into their designs where possible, it was not always a high priority.

The respondents provided information on a number of both successful and unsuccessful BMP installations and projects. Some factors common among the successful projects included use of source control, treatment trains, and effective treatment basins. One of the more interesting factors identified as contributing to a project's success was a sense of stewardship developed by local property owners. Many respondents noted, however, that it is difficult to actually gage the success of a BMP or project due to lack of monitoring data. Responses about unsuccessful installations seemed to focus on proprietary treatment systems, the potential failure of infiltration systems and failure to establish vegetation. Monitoring data was again pointed to as necessary to determine the true success of a project. Interestingly, several specific projects were identified as both successful and unsuccessful by different respondents, highlighting the fact that the definition of a successful project can vary greatly among water quality practitioners in the Tahoe Basin.

5. Regulatory and Performance Standards

The design standard that most significantly affects water quality BMP design in the Tahoe Basin is the 20-year 1-hour design event. Other regulatory requirements identified as important by the respondents were concentration standards and storm water permit requirements. Many interviewees noted that they were aware of the concentration standards and attempted to achieve these, but that the standards were virtually impossible to meet. As a result, the 20-year 1-hour design event frequently functioned instead as the de facto standard. Many respondents also noted that they designed projects to achieve the 'maximum extent practicable' improvement in water quality. Other important requirements or standards included prohibitions on SEZ impacts, following the preferred design approach (Formulating and Evaluating Alternatives approach) and working together with regulating agencies to develop an acceptable design.

The interviewees had somewhat mixed opinions about how well the current standards represent water quality performance. A number simply stated that they did not think they were useful standards, while many further expanded on this position by noting that surface water discharges standards were unattainable, that the connection between the standards and lake clarity is unclear and that the standards did not reflect seasonal conditions. Other respondents stated that while the concentration standards are stringent, water quality would certainly improve if they could be met. Opinions were divided on the 20-year 1-hour storm event as well. While some thought that this was a reasonable design event or "better than nothing", others thought that it was too large and not based on solid scientific analysis.

The interviewees were then asked to suggest changes to the current standards based on their experience. Many cited the forthcoming TMDL process as an improvement over the current standards, although some expressed doubts about how the process would function in a practical manner. Several respondents noted that an effort must be made to determine or establish BMP efficiencies in support of the TMDL process. Others suggested that areas with the greatest pollutant sources should be identified and prioritized to focus available resources. Pre- and post-project monitoring was also recommended to establish a scientific basis for standards.

The interviewees were questioned about what numerical values are typically computed to determine whether a BMP provides an acceptable level of treatment. More than half the respondents have performed volume and peak flow reduction calculations, while a smaller percentage have performed concentration and pollutant load reduction calculations. Methods used to perform the latter calculations included application of a proprietary watershed model, the Formulating and Evaluating Alternatives (FEA) spreadsheet (SWQIC, 2004) and incorporating estimates of BMP effectiveness. The most advanced set of concentration and load calculations identified during the interview process were performed in support of the Tahoe City Wetlands project, where the designers determined pollutant concentrations into and out of the project. The only other type of load computation performed with any regularity is application of the Universal Soil Loss Equation to determine pre-project sediment rates, typically from road shoulders that will be treated with curb and gutter.

The majority of the respondents reported that their institution had either performed or recommended performance of monitoring on water quality improvement projects. Most of these respondents, however, stated that monitoring was generally irregular in nature and driven by factors such as Technical Advisory Committee input and the need to determine the performance of a particular BMP.

6. <u>Analytical Tools and Data Sources</u>
A range of sources was identified for runoff, precipitation, soils, vegetation, topography and land use project design information. The vast majority of this data appears to be collected from standard government agencies, such as Natural Resource Conservation Service soils data, United States Geological Survey flow data and Tahoe Regional Planning Agency land use data. Some agencies also collect their own project precipitation and flow data, and site reconnaissance is frequently used to confirm available maps and gather additional information.

The most commonly used hydrologic tools are the rational method and the SCS curve number/HEC-1 method, although a little less than half of the respondents reported using or reviewing a continuous model (such as the Storm Water Management Model [SWMM]) at least once. Other hydrologic tools that were cited included a proprietary watershed model, regression equations and the FEA spreadsheet. Respondents demonstrated a range of opinion about the effectiveness of these tools. Some interviewees thought that the available hydrologic tools were very effective and provided a consistent methodology, while others stated that they were only as good as the input data, resulted in overly conservative volumes and flows for BMP design, and were not very applicable to small, highly urbanized watersheds. Many respondents liked the simplicity and ease of the rational method, but realized that other methods provided better estimates of flows and volumes if time and budget allowed.

Respondents have used a variety of water quality tools to determine runoff water quality and, to a lesser extent, estimate BMP effectiveness. These include flow monitoring (both visual and sample-based), the FEA spreadsheet and application of professional opinion. A suite of software tools was also identified: SWMM, a proprietary watershed management model and the Watershed Erosion Prediction Project (WEPP) model. A large number of respondents reported, however, that they have not used any tools to determine runoff water quality or BMP effectiveness. Of those respondents who have used the software tools noted above, most were only moderately satisfied with the results. They felt that they were adequate for making rough estimates, and that the most significant problem in applying these tools is a lack of good input data for both pollutant loadings and BMP efficiencies. The exception to this general perception was the WEPP model, which was reported to provide fairly good results when applied appropriately. In addition, monitoring was noted to provide a good qualitative estimate of water quality.

The vast majority of interviewees reported that water quality projects are typically based on design storms, although one or two respondents had reviewed or considered designing a project using a continuous modeling approach. The advantages of design storms were identified as simplicity, satisfaction of permit requirements, cost effectiveness and conservatism. The disadvantages of design storms were listed as a lack of information on long-term trends, no method of accounting for snow, no direct connection to water quality and over-design of water quality BMPs. The benefits of continuous modeling were seen as its capability to investigate a range of hydrologic conditions, such as sequential storm events, seasonal events and different scenarios in wet and dry years. The disbenefits of continuous modeling were identified as intensive data requirements, the limited availability of adequate data to get meaningful results and a greater level of technical expertise necessary to develop a model.

Finally, respondents were asked to suggest any other tools that might be used for hydrologic and water quality purposes. Several software tools were identified, including SWMM, WEPP, HSPF (a continuous hydrologic model) and WASP, the EPA's receiving water model. One interviewee commented that without better input data, however, it did not matter what tool was applied. In addition to software tools, one interviewee suggested developing frequency-exceedence curves to provide flow design data for a range of conditions.

7. Maintenance and Monitoring Practices

The interviewees were asked a series of questions about current maintenance and monitoring practices. The project proponents are typically responsible for maintenance of BMPs; this includes counties, general improvement districts, the City of South Lake Tahoe, the state Departments of Transportation and the United States Forest Service. The respondents unanimously stated that maintenance was required for all BMPs, although there were discrepancies among the respondents regarding maintenance activities and schedule.

Respondents stated that maintenance is ideally performed at least twice annually, once in the spring and once in the fall. This is cost- and time-prohibitive to some agencies, however. Most BMPs are maintained annually or on an as-needed basis between May and October, with some agencies reporting that they are at the limit of their maintenance capacity. Maintenance frequency and activity is generally required for newer projects as part of funding agreements but may not be specified for older projects. Maintenance activities typically consist of using a vacuum truck to vacuum sediment out of sand traps and drainage inlets, street sweeping and any reconstruction necessary to ensure the performance of the BMP. Some respondents did not state a reporting requirement, but several noted that they prepared an annual report for Lahontan and TRPA that summarized tons of sediment collected and number of BMPs maintained.

Approximately half the respondents stated that virtually 100% of their projects had a visual monitoring requirement for at least 2 to 4 years after construction. Water quality monitoring requirements were much less common, with less than half the respondents reporting flow sampling requirements for less than half of their projects. When monitoring is required, slightly more than half of the respondents specify the monitoring schedule and reporting requirement. In other cases, oversight agencies such as the TRPA and the CTC specify these requirements, although in some instances no monitoring or reporting is required at all. When monitoring is required, it is typically visual. On the infrequent occasions where water quality monitoring is performed, upstream and downstream sampling is generally performed, although some agencies are only concerned about effluent concentrations.

Slightly less than half the respondents reported modifying a current or proposed BMP design based on monitoring results. The monitoring data used in these cases included both visual data and water quality sampling data. One interesting case involved pre-project water quality sampling that identified the pollutants of concern at the project site and allowed the design to be modified to be more cost-effective. Caltrans has perhaps the most comprehensive monitoring program in place, with the intent to modify its designs based on long-term water quality monitoring results. Roughly two-thirds of the respondents stated that they had water quality monitoring data available. Some data appears to be available for individual BMPs, although many monitoring sites are located below several BMPs in series or an entire project area. A smaller number of respondents noted that they planned to use monitoring data to modify their designs in the future, but do not have adequate data available now.

8. Summary

The interviewees were asked about their experiences with methodologies used to estimate project effectiveness during the design phase. A little less than half stated that they were not aware of any such methodologies, but the remainder identified a number of possible approaches. These included the TMDL process, applying hydrologic and water quality modeling tools, determining a qualitative value for net water quality benefit and using flows as a surrogate for pollutant loads. Slightly less than half of the respondents noted that several of these approaches were already being utilized by their institutions, although nothing has been done yet on a very large scale.

The interviewees also pointed to a number of storm water management programs outside the Tahoe Basin that had implemented a similar approach. The most commonly mentioned program was Chesapeake Bay, which was noted for its adaptive management approach and negotiated values for BMP effectiveness. Several state programs were identified as well, including those of Maryland, Florida, Texas and King County in Washington. In addition to government programs, water quality modeling has been performed in Michigan using a proprietary watershed model.

Finally, respondents were given an opportunity to offer comments that might be helpful to the current project. A lack of good data on both pollutant loadings and BMP efficiencies was identified as a significant gap, and concerns about costs, availability of funding and required levels of maintenance were also voiced. A number of respondents recommended looking at programs and practices implemented outside of the Tahoe Basin for possible guidance. Many respondents noted that they supported the TMDL program and believed or at least hoped that it would go a long way towards addressing storm water management in the Tahoe Basin.

C.4 Compilation of Interview Results

The results of the interviews were compiled into tabular format to provide a condensed summary of the responses. An effort was made to report the responses as directly as possible, without added interpretation of the respondent's statements. When several respondents answered in a similar manner, however, their comments were typically reduced into a single response that best represented their statements. For some questions, information about the number and type of respondents was included to better quantify the answers. The results are presented in Tables C.2 through C.9.

Table C.2 Issue 1 – BMP Selection, Question 1

Question 1. Please rank the relative importance/frequency of use of the following elements in BMP selection by your organization (1-13): **- ALL RESPONSES -**			
Elements in BMP Selection	**Regulators/Funders**	**Implementers**	**Consultants**
Pollutants of concern	1, 2	1, 5, n/a, 1, 4, 6, 8, 1, 1	8, 1, 2/1, 4
Forms of the pollutants of concern (e.g. dissolved vs. total)	4, 3	1, n/a, n/a, n/a, 10, 11, 9, n/a, n/a	10, 2, 3/2, 4
Particle size and density	2, 3	1, 5, n/a, n/a, 11, 10, 10, n/a, n/a	11, 2, 1/2, 4
Quantitative load/concentration reduction requirements	3, 1 (though not necessarily quantitative requirements)	5, n/a, n/a, n/a, n/a, 12, 11, n/a, n/a	6, 2, 11/1, 4
Other regulatory requirements	5, n/a	5, n/a, n/a, n/a, n/a, 5, 13, 3, 13	7, 2, 10/3, n/a
Monitoring data on treatment effectiveness	6, 7	n/a, 6, n/a, n/a, n/a, 9, 7, n/a, n/a	12, 1, 8/3, 5
Technical references on treatment effectiveness	6, 10	n/a, 6, n/a, n/a, n/a, 8, 12, n/a, n/a	9, 1, 9/3, 5
Experience on previous projects	7, 6	4, 4, 1, n/a, 5, 4, 1, 7, n/a	2, 1, 4/1, n/a
Drainage/flood control benefits	13, 9	6, n/a, n/a, n/a, 12, 7, 5, 6, 13	4, 3, 7/2, 1
Maintenance requirements	8, 8 (also maintenance abilities and responsiveness)	2, 2, 2, n/a, 3, 3, 4, 4, 3	3, 2, 6/2, 3
Site constraints	9, 5	3, 1, 3, n/a, 1, 1, 3, 2, 2	1, 1, 5/1, n/a
Downstream effects (e.g. erosion from discharged flows)	10, 4	6, 3, n/a, 2, 2, 6, 5, 4	5, 1, 12/1, n/a
Other factors (please identify and rank)	none	5 – BMP effectiveness or load reduction 2 – runoff control to prevent concentrated runoff 2 – funding 1 – how a BMP fits goals and objectives of project	2 – Cost/cost effectiveness
General comments	1. Need to look at whole problem first, taking a holistic approach, then look at individual factors above.	1. Regulatory requirements are not given more importance because they tend to be guidelines on concentration limitations, not averaged or volume-based, and also tend to be unrealistic given the current technology and limitations of the BMPs that are implementable. 2. Primary criteria is 20-year 1-hour standard	1. A holistic approach is taken with projects, so it is difficult to prioritize these 2. Difficult to rank, as projects are generally designed as holistic systems. Depends on clients' needs.

Notes:

1. This table records the ranking assigned by respondents to each element listed in the first column (e.g., 1,2 indicates that one respondent ranked this element as most important, and one ranked it as second most important).
2. In the case where two people from the same organization had different opinions, the response is shown as first respondent's ranking/second respondent's ranking (e.g. 1/5).
3. Some respondents found it difficult to discretize their responses into 13 categories, and chose instead to rank them in larger groups.
4. An "n/a" means that the respondent did not assign a value to that criterion, usually because it was unimportant to him or her.

Table C.3 Issue 1 – BMP Selection, Question 1 – Average Rankings

Question 1. Please rank the relative importance/frequency of use of the following elements in BMP selection by your organization (1-13):

- AVERAGE RANKINGS -

	Regulators/Funders	**Implementers**	**Consultants**
Pollutants of concern	1.5	4.1	3.2
Forms of the pollutants of concern (e.g. dissolved vs. total)	3.5	9	4.2
Particle size and density	2.5	8.6	4
Quantitative load/concentration reduction requirements	2	9.8	4.8
Other regulatory requirements	5	8.8	6.4
Monitoring data on treatment effectiveness	6.5	9.1	5.8
Technical references on treatment effectiveness	8	9.6	5.4
Experience on previous projects	6.5	5.1	3.6
Drainage/flood control benefits	11	8.8	3.4
Maintenance requirements	8	3.7	3.2
Site constraints	7	2.9	3.6
Downstream effects (e.g. erosion from discharged flows)	7	4.2	5.8

Notes:

1. A ranking of 10 was assumed for all “n/a” responses for the purposes of calculating an average ranking to reflect the fact that elements identified as “n/a” were relatively unimportant to the respondents.

Table C.4 Issue 1 – BMP Selection, Question 2

Question 2. Please briefly describe the use of the five most important criteria identified above in BMP selection.			
Element Rank	**Regulators/Funders**	**Implementers**	**Consultants**
1	1. Pollutants of concern/forms of pollutants of concern Important to select BMPs that address fine particles, nutrients 2. Load/concentration reductions This is the primary goal/objective of the program	1. Pollutants of concern/forms of pollutants of concern/particle size and density This is the ultimate goal of water quality improvement projects. 2. Experience on previous projects Knowledge of what works and what doesn't work is used to design projects 3. Site constraints Constrained by ROW, terrain and utilities – often drives a project	1. Site constraints BMP must fit in area available, or it will not be constructed or work 2. Pollutants of concern/forms of the pollutants of concern/particle size and density Need to select a BMP that addresses the targeted pollutants 3. Drainage/flood control benefits Projects need to handle these aspects first
2	1. Particle size and density Same reasons as #1-1 above. 2. Pollutants of concern Need to strategically target pollutants to build projects that maximize water quality improvement	1. Maintenance requirements Ease and cost of maintenance are significant concerns 2. Load/concentration reductions This is the primary goal/objective of the program 3. Downstream effects Must consider downstream effects of collecting and concentrating flow 4. Funding BMP selection and design can be affected by lack of available funding 5. Site constraints Attempt to use infiltration basins as much as possible, but site constraints often exclude these	1. Experience on previous projects Judgment can be exercised in selection of BMPs based on previous project experience 2. Monitoring data on treatment effectiveness Very valuable for engineering design, but consistent data is difficult to obtain 3. Cost/cost effectiveness Cost drives everything
3	1. Quantitative load/concentration reduction requirements Project proponents must make an effort to meet numeric effluent standards and maximize pollutant removal 2. Forms of pollutants of concern/particle size and density Same reasons as #2-2 above.	1. Site constraints Limited to ROW, have conflicts with utilities, topography, groundwater, soils, TRPA land capabilities 2. Maintenance requirements Costs, lack of personnel cause maintenance to be a factor in design 3. Other regulatory requirements Lahontan permit requirements may drive BMP selection	1. Maintenance requirements In general, BMPs that require less maintenance are more effective (especially over the long term) 2. Site constraints Review site to ensure that design will work and investigate any new technologies that may assist in mitigating constraints

Question 2. Please briefly describe the use of the five most important criteria identified above in BMP selection.			
Element Rank	**Regulators/Funders**	**Implementers**	**Consultants**
4	1. <u>Forms of pollutants of concern</u> Same reasons as #3-1 above 2. <u>Downstream effects</u> Considering downstream effects is important to implementing a watershed approach to water quality projects	1. <u>Experience on previous projects</u> Past experiences influence BMP design 2. <u>Maintenance requirements</u> Non-existent funding for maintenance drives design of BMPs to have minimal maintenance requirements	1. <u>Drainage/flood control benefits</u> BMPs should be designed, constructed and maintained to handle large events so that they do not fail 2. <u>Maintenance requirements</u> Maintenance requirements should be considered in BMP design and kept is minimal as possible, given other requirements 3. <u>Pollutants of concern</u> Projects must address these
5	1. <u>Other regulatory requirements</u> SEZ regulations: no disturbance and discharge to SEZ must be pre-treated 2. <u>Site Constraints</u> These may drive a project due to limitations.	1. <u>Other regulatory requirements</u> Must consider other requirements because they are tied to project permitting 2. <u>Quantitative load reduction</u> Must target these to meet permit requirements 3. <u>Drainage/flood control benefits</u> Pursue reduction of pollutants through minimization of high-flow erosion on road shoulders 4. <u>Downstream effects</u> Erosion control and channel stabilization must be considered for locations of concentrated flow	1. <u>Drainage/flood control benefits/downstream effects</u> Public safety is paramount and effects of BMPs should be considered.; a BMP should not cause downstream erosion

Notes:

1. A portion of the respondents did not provide detailed answers to this question.

Table C.5 Issue 2 – BMP Design Criteria

Questions	Responses
1. What criteria, if any, do you use to size volume-based controls and what criteria, if any, do you use to define the drain time for volume-based controls?	Sizing of volume-based controls: • The 20-year 1-hour storm (1 inch of precipitation) is most commonly used. The majority of respondents identified this as their primary water quality design event. - it may be difficult to get this volume due to site constraints - many respondents try to get more than this volume if at all possible - typically applied to the entire project area, although occasionally applied to ROW only - typically from impervious area only • Flow duration results from FEA spreadsheet • Procedure based on a relationship between watershed size, percent imperviousness and basin size • Apply a multiplier of 1 to 2 times the mean storm over the watershed Drain time criteria: • Many respondents referenced a 72-hour drain time for vector control, although one respondent noted recent research which indicates that the mosquito life cycle is 11 days, possibly allowing for longer drain times • Other standard drain times ranged from 1 to 4 days, with a need to address vector control with the longer drain times • Some respondents stated that they did not use a standard drain time • Apply Stoke's Law and try to maximize settling of particle • Drain ponds in such a way as to maximize treatment • Drain times depend on site-specific conditions (soils, loss rates)
2. What criteria, if any, do you use to size flow-based controls?	• 10-year 24-hour storm, primarily for conveyance - one respondent would like to use a larger flow, but space constraints preclude this • 6-year 24-hour storm • 2-, 10-, 25-, 50- and 100-year storms, with the last four based on regulatory requirements; these requirements depend on which agency is involved • 100-year 24-hour storm to check flooding • FEA spreadsheet • Detention time for sand vaults, although larger tributary areas make long detention times difficult to achieve • Empirically sized, keeping flow velocity and depth low • Check for standard minimum velocities of 2 ft/s for cleaning and maximum velocities of 10 ft/s to prevent scour
3. What criteria, if any, do you use for selecting the geometry of BMPs (e.g. aspect ratio, multiple or single cells, etc.)?	• Information in a number of references regarding length-to-width ratios, recommended depths for retention facilities and wetlands, and geometries for settlement: Goldman's book, FHWA manual, Maryland manual, Caltrans manual • Longer hydraulic retention times • Particle settling size data • Aspect ratio/volumes for ponds • Multiple cells developed to address various types of pollutants • Wet ponds are preferred over dry ponds • Shallow and long basins to maintain vegetation • Aesthetics/try to retain trees • More cut than fill in constructing ponds

Questions	Responses
	• Consider maintenance in design: use of concrete forebays for removing sediment • Based on site constraints • Prevent short-circuiting in ponds • FEA spreadsheet
4. Which of the following hydrologic standards do you design your BMPs to meet? Please indicate whether they are used for design of conveyance capacity, water quality performance, or both.	• 2-year peak flow - water quality (7 respondents) - conveyance (1 respondent) - temporary BMPs (1 respondent) - neither (3 respondents) • 2-year volume - water quality (5 respondents) - neither (7 respondents) • 10-year peak flow - conveyance (9 respondents) - both (1 respondent) - neither (2 respondents) • 10-year volume - water quality (1 respondent) - neither (10 respondents) - both (1 respondent) • 100-year peak flow - check flooding/conveyance (11 respondents) - neither (1 respondent) • 100-year volume - flood concerns/conveyance (4 respondents) - neither (8 respondents) • Other - 20-year 1-hour (11 respondents) - per FEA, 2- and 10-year 24-hour (1 respondent) - 1-year for sizing of basins (1 respondent) - 2- and 5-year volumes if 20-year 1-hour can’t be met (1 respondent) - 2-, 5-, 10-, 25-year flows for all projects (2 respondents) - 50-year flow into SEZ (1 respondent) - no net increase in peak flows or volumes (4 respondents) - drainage law: no downstream impacts (1 respondent)
5. What soils and groundwater criteria, if any, are used for infiltration BMPs?	• NRCS soils information • 5 feet minimum separation to seasonally high groundwater, or 1 foot bare minimum (per Lahontan); if less distance, use pre-treatment • 10 feet minimum separation to seasonally high groundwater (less with permission from Lahontan) • 4 feet minimum separation to seasonally high groundwater • Site basins close to groundwater for vegetation establishment and aesthetics • Avoid standing water in basins

Questions	Responses
	• Soils tests for permeability/infiltration rates • Installation and operation of monitoring well for one year • Test groundwater for quality; no degradation of groundwater quality allowed • Minimum of 0.5 inches/hour infiltration rate • Must drain within 7 days • No compaction of soils in basins
6. What four technical references (i.e. reference books, design manuals, technical papers) do you use most often for BMP design?	• TRPA BMP Handbook • Nevada BMP Handbook • NDOT Water Quality manual • Water Quality Management for Forest System Lands in California – Best Management Practices • FHWA temporary BMP publication • National BMP database • ASCE WEF Manual of Practice • Controlling Urban Runoff - Scheuler • Maryland manual • Erosion Control Handbook - Goldman • Caltrans BMP manual • CASQA BMP manual • Storm water Treatment - Minton • Metcalf & Eddy book • Erosion Control magazine • Notes from seminars and workshops • Bulletins issued by water quality control boards, EPA and other authorities • Research on internet

Table C.6 Issue 3 – BMP Design/Implementation Constraints

Questions	Responses
1. What do you see as the major constraint(s) for designing a project based on water quality treatment performance (concentration-based and load reduction)?	• Capital costs • Maintenance costs and staffing • Limited availability of land in strategic locations (downslope, near project area) • Site constraints: terrain, conflicts with utilities, conflicts with cultural resources • Variability in effluent quality from a range of storms • Lack of data on pollutant loadings and individual BMP effectiveness • Lack of pre-project water quality monitoring data • Current BMP technologies cannot achieve effluent standards- only infiltration works • Infiltration rates may not be high enough • Difficulty in proving compliance with standards; requires extensive monitoring, reporting and enforcement • Difficulty in getting permits • Difficulty in balancing flood control and water quality benefits of projects • No clear path or directive to achieve these standards • Unclear how concentration standards relate to total load reduction

2. What significant constraints would you face in installing non-passive BMPs for water quality treatment (e.g. chemically enhanced BMPs, water transport by pumping, etc.)?	• Capital costs
	• Operation costs and staffing
	• Maintenance costs and staffing
	• Transport/pumping requirements
	• Limited availability of land
	• Installation of infrastructure, conflicts with other in-ground utilities
	• Retrofit costs
	• Technical challenges
	  - ability to handle wide variability in flows and volumes
	  - lack of technology performance history
	• Adequate monitoring required to ensure no release of treatment chemicals
	• Concerns about effluent loadings due to chemically enhanced treatment
	• Aesthetics, noise
	• Difficulty in getting permits
	• Liability concerns
	• Resistance from project proponents

Questions	Responses
3. What are the three most significant property or land use constraints you face when designing a project?	• Availability of undeveloped land in strategic locations (downslope, flat, near project area) • Availability of willing sellers • Cost of available land • Secondary home ownership makes it difficult to work with property owners • Proximity to private property • Property owner contact performed late in project design schedule • Political constraints • Difficulty in collaboration between agencies when multiple ROWs are involved • Lack of ROW • Reluctance on part of project proponents to obtain easements due to intense permitting requirements, maintenance requirements and liability for improvements on private property • Confined space in ROW – conflicts with utilities, trees, parking • Topography – very steep slopes in some areas (particularly east side of lake) • Soil contamination may prevent infiltration • Limited vegetation removal allowed • Cannot disturb SEZs • Pedestrian and vehicular traffic which causes destruction of restoration projects

Table C.7 Issue 4 – Typical Practices

Questions	Responses
1. Do you generally prefer underground or aboveground BMPs, and why?	• No strong preference (6 respondents) - generally driven by site constraints - effectiveness more important than above- versus underground • Aboveground - generally easier to construct - generally easier to maintain - ability to visually monitor - typically more cost effective than underground - can design larger facilities - prefer land spreading/treatment in large shallow ponds to take advantage of soil horizon and root systems for uptake - allows incorporation of vegetation in the treatment process - utilizes evapo-transpiration - West Nile virus becoming a concern for use of aboveground BMPs - aesthetics may be a positive or a negative - safety issues (ponds must be gated) - freeze/thaw concerns • Underground - moving towards underground because of concerns about standing water and better site utilization - useful for treatment trains - work better in urbanized areas - private property owners typically prefer underground to maximize their site - lots of potential for underground BMPs that has not yet been tapped - require more maintenance: special equipment, safety concerns
2. Have you ever specified multiple BMPs or a treatment train, and if so, what were the reasons for such a choice?	Yes. (13 respondents) - they provide a higher level of treatment, including polishing effect - used to target multiple pollutants that no single BMP could address - used to meet regulatory requirements - driven by space constraints - implemented based on past experience of what works - innovative approach - reflects preferred design approach - range from simpler sand vault pre-treatment to more advanced multiple BMPs in succession No. (2 respondents)
3. Please note the types of BMPs you have used one or more times and explain why these BMPs were selected for multiple applications.	• Source control BMPs (13 respondents) - revegetation and placing rock protection on slope - have to ensure that hydrologic runoff is not increased - always use to maximum extent possible - using more and more • Pervious drainage systems (10 respondents) - always used except when groundwater is too shallow • Bioswales (12 respondents)

Questions	Responses
	- frequently used • Proprietary treatment systems (9 respondents) - suggest for space-constrained areas • Dry detention basins (13 respondents) - typically used when groundwater and infiltration rates are favorable • Wet detention basins (10 respondents) - typically used when groundwater is shallow • Extended detention basins (9 respondents) - typically used when hydrology regime allows • Sediment traps – sumps (12 respondents) - critical for sand trap areas - typically used on all drainage inlets • Sediment traps – passive hydraulic (12 respondents) - series of 8-foot deep vertical CMPs - often used when space precludes other BMPs • Sediment traps – active hydraulic (7 respondents) - often used when space precludes other BMPs; maintenance is a big issue • Oil and grease traps (12 respondents) - used in parking lot applications; may be overkill in commercial areas, but important in industrial areas - typically used on drainage inlets • Infiltration dry wells (11 respondents) - typically used on private projects • Infiltration galleries (10 respondents) - there are concerns about clogging of soils beneath galleries because these cannot be maintained - typically used on private projects • Constructed wetlands (8 respondents) • Natural wetlands (6 respondents) - must use adequate pre-treatment • Coagulation/flocculation systems • Filtration systems (7 respondents) - often used when space precludes other BMPs • Adsorption systems (4 respondents) - currently an experimental application • Other - shallow spreading across vegetation (1 respondent) - curb and gutter (1 respondent) - timber harvest management practices (1 respondent) - road building/mining/recreation BMPs (1 respondent) BMP selection comments: • Site- and land use-dependent • Prefer infiltration basins because they treat a large range of flows

Questions	Responses
	• Don't believe that flow-through systems are effective • Maximize removal of identified pollutants • Cost is a factor • BMPs are selected because they haven't been proven to not work • BMPs are selected because they are proven to work • Past project experience is a factor • Use BMPs accepted/recommended/required by regulatory agencies • Low-maintenance preferred • Try to avoid rock-lined ditches • When following the preferred design approach, many of these are evaluated for use in project area • Given a large range of projects, many different BMPs have been tried
4. In what situations, if any, do you design high flow bypasses for BMPs?	• Design BMPs with a high flow bypass most or all of the time • Imperative for volume-control BMPs (e.g. ponds, sand traps, infiltration ponds) • Most sediment treatment vaults and basins especially if there is tributary flow that is relatively 'clean' • Typically used on smaller treatment systems • Design for conveyance first, then water quality • High flow bypasses as part of proprietary treatment systems. • Used for flow-through BMPs, recommended but not required • Used for regional/ area-wide BMPs, not usually for commercial sites unless needed because of shallow groundwater or site constraints • Do not design high flow bypasses
5. Please describe one or two of your most successful BMP installations and identify what factors made them successful. (The names of individual projects are intentionally omitted here.)	Wetland Basins - aesthetically pleasing - appear to function well Extended Detention Basin System - stable - treatment train approach Storm water Management Project/Road Improvements - infiltration gallery below road: good site utilization - high infiltration rates Storm water Management Project - routed clean water around urbanized area - used watershed approach Water Quality Basin - concrete forebay that is easy to maintain - downstream basin had vegetation - unknown whether it is truly effective Storm water Management Project - investigated watershed above project - reduced flows from public lands - reduced probability of flow path failure at bottom of watershed - emphasized infiltration

Questions	Responses
	Wetland Basin - continuously wet, so it’s a well-established wetland - high treatment of nutrients - long flow path/residence time Water Quality Basin - concrete forebay captures a large amount of sediment Activated Alumina Infiltration Basin - appears to be working well - does raise pH, however Storm water Management Project - successfully stabilized steep slopes with vegetation - temporary irrigation became semi-permanent irrigation - private property owners have taken stewardship of slopes BMP Retrofit Project - source control - reduced width of road - installed curb and gutter - used a basin sized for greater than the 20-year 1-hour storm - sheet flow into SEZ General Comments - source control projects - slope stabilization: either structural or non-structural - curb and gutter on steep, eroding shoulders - can’t tell if any projects have been successful because the effectiveness has not been quantified - difficult to tell what’s working- projects have not been in place long enough
6. Please describe one or two of your least successful BMP installations and identify what factors caused difficulties. (The names of individual projects are intentionally omitted here.)	Vortex Separator Vault - not maintained adequately - flows re-suspend sediments and fine particles - possibly no high-flow bypass Vortex Separator Vault - undersized - possibly incorrect inlet pipe slope - sediment is flushed out of BMP Storm water Management Project - concentrated flow - not enough emphasis on interaction of urbanized areas and SEZs Filter Vault Storm water Management Project - no curb and gutter, so snow removal scrapes shoulders and mobilizes sediment - low connectivity to lake, so primarily a flood control project - politically driven, not a water quality control project Water Quality Basin - huge concrete forebay - aesthetically unpleasing

Questions	Responses
	Storm water Management Project - revegetation failed - possibly due to continued disturbance by walking or driving - possibly lack of sufficient soil nutrients - possibly haphazard installation- lack of fertilizer, minimal monitoring General Comments - any gravel-style infiltration bed or gallery is prone to clogging and almost impossible to maintain - infiltration basin sited on a clay lens with only outfall over lip of basin - older erosion control projects - proprietary systems - double-barreled sand traps have limited efficiency and don't work for a range of flows - lack of monitoring to check whether projects are working - rock-lined channels; rocks get sucked into Vactor trucks - infiltration trenches that get bypassed or short-circuited - poor siting of sediment traps - failing to take a watershed approach - mixing clean water with pollutant-laden water - lack of knowledge about utilities causes problems during construction, which generates in-field redesign that may compromise original intent of project - don't know if these are unsuccessful, because no information is available: conveyance (curb and gutter) and proprietary systems

Table C.8 Issue 5 – Regulatory and Performance Standards

Questions	Responses
1. What current regulatory standards significantly affect your BMP designs?	• Regulatory concentration standards for discharges (4 respondents) - infiltrate as much as possible because surface water discharge regulations are so restrictive they almost impossible to meet - attempt to get pre-project monitoring data, try to meet the pre-project conditions - in theory, but not in practice • Regulatory load standards for discharges (1 respondent) • Storm water permit requirements (4 respondents) - all projects require Lahontan permits- they check plans and BMPs for adequacy and make a judgment regarding approval - NPDES permits - TRPA permits - NDEP permits • 20-year 1-hour volumes (12 respondents) - virtually what all design is based on - more volume is often treated if at all possible • Others (please list) - SEZ requirements: no disturbance, pre-treatment of flows - 401 water quality certification (dredge and fill) - work with TRPA and NDEP to reach an acceptable design - design to ‘maximum extent practicable’ - City and County Drainage Standards - Caltrans projects target a particular particle size - design BMPs to convey 10-year, 24-hour storm - follow preferred design approach (FEA approach) - West Nile criteria - concerns about drinking water supplies

Questions	Responses

2 How well do you think these standards represent water quality performance?	• Not very well (5 respondents)
	• 20-year 1-hour:
	  - a reasonable design storm - it is guidance, not a requirement
	  - may be too large because of lack of space; would like to make shallow channel but large volume makes it difficult
	  - does have the benefit of capturing the 'first flush', but the scientific basis is poor and application may be poor
	  - better than nothing
	• Development of concentration standards seems questionable since the constituent levels came from grab samples that are not necessarily representative
	• If the numeric effluent standards could be met, water quality would be better
	• Do not see a connection between standards and lake clarity
	• Reflect water quality, however, they are not attainable and are not prioritized by highest concentrations
	• Can't determine pollutant load reductions
	• Load reduction achieved but can't meet effluent standards
	• Discharge to groundwater standards attainable through infiltration basins; discharge to surface water unattainable
	• Good for coarse sediment, unknown effectiveness for other constituents
	• Standards do not address seasonal conditions
	• The effluent limits are goals; they do the best they can with the available technology
	• Not enough info on actual BMP performance
	• BMPs seem to work so standards appear appropriate

3. Based upon you experience, what changes would you recommend to these standards?	• TMDL process, though some doubts about how it will work in a practical manner using load allocation based on response in receiving water • Use of lake clarity model to determine acceptable load to lake for level of clarity • Holistic approach that gets to load issue based on land use • Have a numerical goal - percentage reduction or other • Prioritization of areas with greater pollutant sources, and focus resources • Reassess what is realistic for pollutant removal • Eventually will negotiate agreed values on BMP effectiveness • BMPs should be rated on their effectiveness • Regulatory standards should address runoff from areas other than the ROW • Effective pre- and post- project monitoring so the regulations and standards can be based on reliable scientific data instead of arbitrary opinions about what 'works' • Sample during storm events to determine maximum extent practicable with current technology performance, then revise standards • Look at atmospheric deposition, N in snow is higher than current effluent limits • Standard hydrology calculations for every project • No changes

Questions	Responses
4. Do you compute numerical values for any of the following to determine whether a particular BMP or series of BMPs provides an acceptable level of treatment?	• Volume Reduction (9 respondents) • Peak flow reduction (8 respondents) • Concentration reduction (6 respondents) - performed for wetlands project - determined in relative terms - used estimates of BMP effectiveness - used FEA spreadsheet • Pollutant load reduction (6 respondents) - used FEA spreadsheet - proprietary watershed management model - used a range of BMP efficiencies from national database • Other measure - USLE for sediment Comments: - these are acknowledged to be estimates - none of these are calculated- qualitative estimates only
5. Does your institution regularly use water quality discharge monitoring to demonstrate BMP performance?	• Yes, at some level (11 respondents) - used to do more, but have not done as much lately due to cost versus value - irregularly perform monitoring; typically in response to direction from TAC - some CEQA findings may require mitigation monitoring - required if there is storm water discharge to surface water during construction - use in pilot studies to examine new technologies - have performed monitoring to look at project effectiveness as a whole, but not individual BMPs - occasionally monitor to determine performance of expensive BMPs • No (4) - due to lack of funding

Table C.9 Issue 6 – Analytical Tools and Data Sources

Questions	Responses
1. What typical sources do you use for runoff data, precipitation data, soils data, vegetation data, topography, vegetation, and land use data?	• Runoff data - flow gages installed at each project - County Drainage Manual procedures - runoff from gaged watersheds on the west shore - data from previous projects • Precipitation data - latest NOAA - City of South Lake Tahoe weather stations - locally installed precipitation gages - data from previous projects • Soils data - NRCS soils data - geotechnical assessments - data from previous projects • Vegetation data - site reconnaissance - TRPA GIS - USFS - TIIMS - data from previous projects • Topographical data - aerial base - USGS maps - site surveys - data from previous projects • Land use data - TRPA land capability maps - zoning maps - data from previous projects
2. What hydrologic tools do you use to model runoff flows and volumes, and to model the hydrologic effectiveness of the BMPs?	• Rational Method (8 respondents) • SCS Curve Numbers and Unit Hydrograph (7 respondents) • Other Loss Rate Estimates (2 respondents) • HEC-1 or MHS (9 respondents) • Other Event Models (2 respondents) - regression equations • SWMM, HSPF, or other Continuous Models (6 respondents) • Others (please list) - proprietary watershed model - Storm CAD - SWQIC spreadsheet

Questions	Responses
3. How effective are these tools for this purpose?	• They are all conservative, have niches where they perform best • They are only as effective as the available input data • The Rational method is quick and simple • Not confident in the Rational method, but it is conservative • Confident with SCS and HEC-1 method • SCS is not very applicable to mountainous areas • SWMM is most helpful but requires more data and time • Depends on project area, more difficult to apply to small highly urbanized project areas • Provide a number for peak flows and volumes to design with - do not know how effective they are, but they do provide consistency • These provide large flow rates and volumes, which result in large facilities - work well for designing drainage facilities that are not geared towards erosion and water quality • Effective for conveyance but not effective for BMPs
4. What water quality tools do you typically use to determine runoff water quality, and to determine the water quality effectiveness of the BMPs?	• Flow-based monitoring data • Visual monitoring of flow during storm events • FEA spreadsheet • Professional opinion and the limited information available - Use TRPA or Lahontan “typical” concentrations by surface type, then apply estimate of BMP efficiencies • On-going BMP monitoring • Pollutant Load Reduction Tool within Watershed Management Model – EPA • SWMM • CDM’s Watershed Management Model • WEPP model - watershed erosion prediction project model, used for determining erosion from roads and hillslopes in undeveloped areas • No software tools used
5. How effective are these tools for this purpose?	• Monitoring is effective and can identify success or failure of the BMP • Visual monitoring is reasonably effective for things one can see, not effective for things one cannot see; gives a good qualitative feel for water quality • Proprietary model is a start, need BMP effectiveness estimates so have to make assumptions, can’t handle parallel BMPs, have to make many assumptions regarding land use, water distribution, change in runoff concentrations, lacks field validation. • Relatively effective - decent for rough estimates, qualitative data is reasonable, not getting much quantitative data. • WEPP is very useful for projects, used for comparison purposes, not an estimate of actual loads. Create pre- and post-project model and compare results. Use it to find areas where there are problems even after BMPs are added; essentially identifying areas that contribute significantly to pollutant loadings, said to have 50% accuracy • Do not know - seem to work but may not be effective at all • They are little more than assigning a number to an estimate made with insufficient data
6. Are designs typically based on design storms or continuous modeling?	• Design storms – typically (12 respondents) • Continuous modeling – occasionally (2 respondents)

Questions	Responses
7. What do you see as the advantages and disadvantage to each approach?	• Advantages of design storms - simple, easy to quantify - have a number to design to - satisfies permits - everyone is familiar with methodology - cost effective - conservative approach • Disadvantages of design storms - does not provide a range of conditions - does not apply to Tahoe conditions because of snow - does not provide information on long-term trends - get flow and volume, but no direct connection to water quality aspect - over design of water quality BMPs • Advantages of continuous modeling - can look at sequential events, seasonal events and annual loads, inter-event phenomena, effects of back-to-back events, different scenarios in wet and dry years - better for load calculations - could be good if more input data were available • Disadvantages of continuous modeling - only as good as input data - intensive data requirements, not enough data currently available - not many people know how to do it
8. Are you able to suggest other tools that you are aware of that could be used for these purposes?	• Without better data, it does not matter which tool is used • Frequency-exceedence curve, as in CA BMP Handbook, provide fairly simple curves that designers can use that synthesize modeling analysis • WEPP • SWMM, if enough data were available • HSPF • WASP - receiving water model from EPA • NetStorm or Storm • Haestad's storm drain model, Civil Design Pond Pack

Table C.10 Issue 7 – Maintenance and Monitoring Practices

Questions	Responses
1. Which entities are typically responsible for maintaining BMPs that you have recommended, funded, or reviewed?	• The project proponents are generally required to maintain their BMPs for 20 years • Private property owners do not have resources to maintain their own BMPs • Municipalities: City of South Lake Tahoe • General improvement districts, homeowners associations • Counties: El Dorado, Placer, Douglas, Washoe • State DOTs: Caltrans, NDOT • Federal: USFS
2. Is maintenance required for BMPs that you have installed?	• Yes, generally all BMPs require some level of maintenance • 20-year maintenance agreements are typically part of funding agreements • There is a large variation in commitment and follow-through by agencies around the basin
3. If maintenance is required, do you specify the maintenance activity and schedule, and a reporting requirement? If yes, what are the most common maintenance activities and frequency?	• Maintenance schedule / frequency - generally perform maintenance twice annually - conventional systems are inspected 2 times per year for the first year, then once thereafter - advantages to cleaning twice per year but is cost prohibitive - inspections 3 times per year and after a major event - maintenance performed on an as-needed basis - maintenance is performed between May and October - maintenance type and schedule depend on level of service (e.g. heavily versus lightly used roads) - currently at limit of maintenance capacity - specified more frequently on recent projects - maintenance is undefined on older projects - annual maintenance; concerns include personnel, confined space entry, lane closures, and equipment • Common maintenance activities - clean out culverts - clean vaults, curb lines, and pipes annually - Vactor truck runs for 8 months of the year, street sweeping directly after storm events - infiltration basins - annual inspection of weirs, overflow pipes and channels - revegetation maintenance such as re-seeding, watering, fertilizing - typically reconstruct BMPs (e.g. water bars) • Reporting - no reporting requirement - volumes are reported to the TRPA, annual maintenance efficiency plan - report volumes, estimate quantities of sediment removed - report to Lahontan: NPDES annual report - report how many BMPs are cleaned - report how much sand is put down and how much is recovered

Questions	Responses
4. What percentage of your projects have a monitoring requirement?	• Visual monitoring - 0% are monitored (3 respondents) - less than 10% are monitored (1 respondent) - 10 – 50% are monitored (2 respondents) - 50 – 90% are monitored - 90 - 100% are monitored (8 respondents) • Water quality monitoring - 0% are monitored - less than 10% are monitored (2 respondents) - 10 - 50% are monitored (3 respondents) - 50 – 90% are monitored (1 respondent) - 90 – 100% are monitored • Visual monitoring during construction • Water quality sampling of any storm event discharge during construction • A number of projects are monitored for 2-4 years after construction
5. For projects with a monitoring requirement, do you specify the monitoring activity and schedule, and a reporting requirement?	• Yes (8 respondents) • Sometimes (1 respondent) • No, do not specify (6 respondents) • Additional comments - TRPA specifies schedule and reporting - CTC specifies annual visual monitoring and has a final reporting requirement - do not have standard protocols - projects are selected for evaluation on an annual basis, reporting is often field notes - monitoring is more reactive than formally planned - as part of permit, inspections are performed in the spring and fall - reporting involves tabulating data in spreadsheets, calculating volumes, reporting flow data and concentration - need to define the objective of monitoring, as this drives the requirements
6. When monitoring is required, is it typically visual or does it involve sampling for flow and/or water quality? Are inflows sampled as well as outflows to determine effectiveness?	• Typically visual (9 respondents) • Some projects require water quality sampling, only measure outflows to establish whether regulatory requirements are met • When sampling is required, upstream and downstream sampling is performed • Only projects monitored by TRG have sampling, both inflows and outflows are monitored in these • Autosamplers are used in sediment basins and flow-through sediment traps for water quality flow in/out • EIP projects have before/after, above/ below, and paired watershed monitoring, monitoring is performed in areas where there are data gaps • Grab samples on pilot projects

Questions	Responses
7. Has a design ever been modified on the basis of monitoring results? If so what type of monitoring data is most effective for this purpose?	• Yes (6 respondents) - based on visual monitoring data - based on flow and water quality data from autosamplers - pre-project monitoring for pollutant concentrations and hydrology/hydraulics informed the design, data showed that oil/water separators were not required and the design was modified accordingly • Caltrans monitoring program is intended to refine its designs, monitoring data includes - Inflow/outflow/EMC data - Storm even flow-weighted composite samples - Multiple events over different types of years and hydrologic event types - Highway traffic areas vs. lower traffic areas - not grab samples • Yes, the BMP Retrofit Program has been implemented to fix old BMPs • No (9 respondents)
8. Do you have BMP monitoring data available?	• Yes (11 respondents) - limited BMP data from wetland and detention basins using autosamplers - NDOT projects, results will eventually be placed on TIIMS - Data will be submitted to the international BMP database - Proprietary data regarding vaults - Located on the Caltrans website - For individual BMPS and overall project effectiveness • No (1 respondent)
9. Do you use monitoring data to modify BMP design or evaluate project effectiveness?	• Yes (5 respondents) • No (8 respondents)

Table C.11 Issue 8 – Summary

Questions	Responses
1. Are you aware of any approaches to designing a methodology to estimate project effectiveness, during the design phase, with regard to pollutant load reduction?	• TMDL process • Utilizing a watershed approach • Proprietary watershed model with theoretical effectiveness of BMPs • Application of hydrologic and water quality models • Net water quality benefit analysis - qualitative • TAC and partnering processes • Use flows as a surrogate for loads, disregarding concentration • Use pre-project monitoring data to assess existing conditions • No (6 respondents)

2. If so, have any of these approaches ever been considered by your institution? If so, to what extent?	• Yes (6 respondents)
	• No (9 respondents)
	  - very open to different approaches
	  - open to changes, with emphasis on practicality
	• TMDL process will be implemented
	• Currently using pre-project monitoring data
	• TAC has been used on previous projects
	• Partnering process has been used on a coordination scale
	• watershed modeling

3. Have you ever heard of these types of approaches being applied in projects inside or outside the Tahoe basin?	• Chesapeake Bay program: adaptive management, negotiated BMP effectiveness • Edwards Aquifer Project in San Antonio • Washington State - King County • Maryland, Florida, Texas storm water programs • developed watershed model for project in Michigan • Caltrans-certified BMPs and standard approach

Questions	Responses

4. Do you have any additional comments that you feel would be useful to this project?	• This is a critical piece of implementation of the TMDL
	• Need to look at processes on a watershed scale, including flow routing and connectivity to the lake and streams
	• Process to selection of Erosion Control Project is unclear by agencies, given their stated water quality goals (e.g. property purchase to locate ponds may be a large waste of money, need monitoring to establish value of ponds)
	• Need honest, un-biased scientific data on BMP performance data in sub alpine environment
	• Pre-project monitoring data would be beneficial
	• They are discouraged from monitoring pre-project events because it's difficult to capture events
	• Currently designing and building projects based on best available knowledge, but this knowledge is limited.
	• There is a big divide between researchers and designers, need to work together better
	• Need to look at work on storm water BMPs performed outside of the Tahoe Basin
	  - TRPA and other agencies tend to think that Lake Tahoe is inventing storm water controls, while this has been done for 30 years in other parts of the country. There is plenty of information on BMP efficiencies from other places.
	  - Believe that there would be a lot of value in looking outside of the Basin for other technologies and applications of storm water treatment BMPs.
	  - East Coast and European technologies seem more advanced than Tahoe methodologies
	  - Ineffective job of incorporating designs from outside the basin and modifying them to fit the basin
	• Maintenance concerns
	  - Maintenance is a very big issue, focus is on design/build but maintenance is mandatory
	  - Funding and personnel shortage for maintenance, basic annual maintenance requires help from outside contractors to complete
	  - Public project funding constraints on maintenance and monitoring should be examined to determine if these constraints are hampering water quality improvement
	  - Regarding hydrology and hydraulics study, would like to see seasonal regression curves

Lake Tahoe Pollutant Load Reduction Methodology
Interview Form

Agency:
Interview Date:
Agency Staff Interviewed:

Interviewer(s):

Interview Questions

Issue 1: BMP Selection

1) Please rank the relative importance/frequency of use of the following elements in BMP selection by your organization (1-13):

    - Pollutants of concern
    - Forms of the pollutants of concern (e.g. dissolved versus total)
    - Particle size and density
    - Quantitative load/concentration reduction requirements
    - Other regulatory requirements
    - Monitoring data on treatment effectiveness
    - Technical references on treatment effectiveness
    - Experience on previous projects
    - Drainage/Flood control benefits
    - Maintenance requirements
    - Site constraints
    - Downstream effects (e.g. erosion from discharged flows)
    - Other factors (please identify)

2) Please briefly describe the use of the five most important criteria identified above in BMP selection.

Issue 2: BMP Design Criteria

1) What criteria, if any, do you use to size volume-based controls and what criteria, if any, do you use to define the drain time for volume-based controls?

2) What criteria, if any, do you use to size flow-based controls?

3) What criteria, if any, do you use for selecting the geometry of the BMPs (e.g., aspect ratio, multiple or single cells, etc.)?

4) Which of the following hydrologic standards do you design your BMPs to meet? Please indicate whether they are used for design of conveyance capacity, water quality performance, or both.

- 2-year peak flow
- 2-year volume
- 10-year peak flow
- 10 year volume
- 100-year peak flow
- 100 year volume
- Other (e.g., no increase in pre-project runoff volumes or flows)

5) What soils and groundwater criteria, if any, are used for infiltration BMPs?

6) What four technical references (i.e., reference books, design manuals, technical papers) do you use most often for BMP design?

Issue 3: BMP Design/Implementation Constraints

1) What do you see as the major constraint(s) for designing a project based on water quality treatment performance (concentration-based and load reduction)?

2) What significant constraints would you face in installing non-passive BMPs for water quality treatment (e.g. chemically enhanced BMPs, water transport by pumping etc.)?

3) What are the three most significant property or land use constraints you face when designing a project?

Issue 4: Typical Practices

1) Do you generally prefer underground or aboveground BMPs, and why?

2) Have you ever specified multiple BMPs or a treatment train, and if so, what were the reasons for such a choice?

3) Please note the types of BMPs you have used one or more times and explain why these BMPs were selected for multiple applications.

- Source control BMPs
- Pervious drainage systems
- Bioswales
- Proprietary treatment systems
- Dry detention basins
- Wet detention basins
- Extended detention basins
- Sediment traps – sumps
- Sediment traps – passive hydraulic
- Sediment traps – active hydraulic
- Oil and grease traps
- Infiltration dry wells
- Infiltration galleries
- Constructed wetlands
- Natural wetlands
- Coagulation/Flocculation systems
- Filtration systems
- Adsorption systems

4) In what situations, if any, do you design high flow bypasses for BMPs?

5) Please describe one or two of your most successful BMP installations and identify what factors made them successful.

6) Please describe one or two of your least successful BMP installations and identify what factors caused difficulties.

Issue 5: Regulatory and Performance Standards

1) What current regulatory standards significantly affect your BMP designs?

- Regulatory concentration standards for discharges
- Regulatory load standards for discharges
- Storm water permit requirements
- 20-year 1-hour volumes
- Other (please list)

2) How well do you think these standards represent water quality performance?

3) Based upon your experience, what changes would you recommend to these standards?

4) Do you compute numerical values for any of the following to determine whether a particular BMP or series of BMPs provides an acceptable level of treatment?

   - volume reduction;
   - peak flow reduction;
   - concentration reduction;
   - pollutant load reduction;
   - other measure.

5) Does your institution regularly use water quality discharge monitoring to demonstrate BMP performance?

Issue 6: Analytical Tools and Data Sources

1) What typical sources do you use for runoff data, precipitation data, soils data, vegetation data, topography, vegetation, and land use data?

2) What hydrologic tools do you use to model runoff flows and volumes, and to model the hydrologic effectiveness of the BMPs?

   - Rational Method
   - SCS Curve Numbers and Unit Hydrograph
   - Other Loss Rate Estimates
   - HEC-1 or HMS
   - Other Event Models
   - SWMM, HSPF, or other Continuous Models
   - Other (please list)

3) How effective are these tools for this purpose?

4) What water quality tools do you typically use to determine runoff water quality, and to determine the water quality effectiveness of the BMPs?

5) How effective are these tools for this purpose?

6) Are designs typically based on design storms or continuous modeling?

7) What do you see as the advantages and disadvantages to each approach?

8) Are you able to suggest other tools that you are aware of that could be used for these purposes?

Issue 7: Maintenance and Monitoring Practices

1) Which entities are typically responsible for maintaining BMPs that you have recommended, funded, or reviewed?

2) Is maintenance required for BMPs that you have installed?

3) If maintenance is required, do you specify the maintenance activity and schedule, and a reporting requirement? If yes, what are the most common maintenance activities and frequency?

4) What percentage of your projects have a monitoring requirement?

5) For projects with a monitoring requirement, do you specify the monitoring activity and schedule, and a reporting requirement?

6) When monitoring is required, is it typically visual or does it involve sampling for flow and/or water quality? Are inflows sampled as well as outflows to determine effectiveness?

7) Has a design ever been modified on the basis of monitoring results? If so, what type of monitoring data is most effective for this purpose?

8) Do you have BMP monitoring data available?

9) Do you use monitoring data to modify BMP design or evaluate project effectiveness?

Issue 8: Summary

1) Are you aware of any approaches to designing a methodology to estimate project effectiveness, during the design phase, with regard to pollutant load reduction?

2) If so, have any of these approaches ever been considered by your institution? If so, to what extent?

3) Have you ever heard of these types of approaches being applied in projects inside or outside the Tahoe basin?

4) Do you have any additional comments that you feel would be useful to this project?

Methodology to Estimate Pollutant Load Reductions

Appendix D – Researcher and Agency Interview Summaries

Final Report

Prepared for:
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D.1 Researcher Interviews

The purpose of interviews with researchers was to assess available technologies to estimate load generation and load reduction at various temporal and spatial scales (e.g., site / BMP scale, project / treatment train scale, or watershed / regional scales). Regardless of the method used, pollutant load generation and reduction estimation requires the estimation of runoff hydrology and quality, as well as BMP hydrology and treatment. Furthermore, sizing criteria are major factors in the ultimate performance of BMPs. Therefore, the interview was organized according to 1) runoff hydrology and quality, 2) BMP hydrology and performance, and 3) BMP sizing criteria.

Phone interviews lasted approximately one hour and were conducted with each interviewee that focused on the following topics:

- Load generation methodologies,
- Load reduction methodologies, and
- BMP design criteria.

Table D.1 lists the researchers interviewed, and summaries of each interview are provided below.

Table D.1: Researcher Interviews

Affiliation	Interviewee	Position
Wisconsin Department of Natural Resources	Roger Bannerman	Environmental Specialist
Center for Research in Water Resources, University of Texas at Austin	Michael Barrett, Ph.D., P.E.	Research Professor
University of Alabama at Tuscaloosa	Robert Pitt, Ph.D., P.E.	Professor of Civil and Environmental Engineering
Colorado State University, Fort Collins	Larry Roesner, Ph.D., P.E.	Professor of Civil and Environmental Engineering
University of Florida	John Sansalone, Ph.D., P.E.	Professor of Civil and Environmental Engineering
Villanova University, Pennsylvania	Robert Traver, Ph.D., P.E.	Professor of Civil and Environmental Engineering
Denver Urban Drainage and Flood Control District	Ben Urbonas, P.E.	Chief

Robert Traver, Ph.D., PE.
Professor, Civil and Environmental Engineering
Villanova University
Director: Villanova Urban Stormwater Partnership
Interviewed on: March 31, 2005 at 2:00 pm EST.

1. Summary of Research
   Dr. Traver briefly summarized his research experience in both individual BMP monitoring and performance, and overall watershed modeling. Most of Dr. Traver's research focuses on individual BMP performance and load generation to these BMPs is directly monitored, not modeled. He helped design and build four research BMPs on Villanova campus (funded by USEPA 319 Program and Pennsylvania Growing Greener Program): porous pavement (rock bed type), infiltration trench draining a parking garage, stormwater wetlands, and bioinfiltration (bioretention/rain garden). All of these were heavily equipped with monitoring equipment (rain gages, flow gages, moisture gages, lysimeters, etc) and have been studied rigorously over the past few years.

   Dr. Traver worked with the Delaware River Basin Commission (DRBC) to model the effect of future development on about 200 square mile watershed containing numerous pristine water bodies. To perform load generation analysis, the Generalized Watershed Loading Function (GWLF) and Arc View GWLF (AVGWLF) models were incorporated. This model uses water balance and soil moisture accounting (daily temperature and rain - 24-hour), with SCS curve number method runoff calculations to model pollutant transport. A build-up/wash-up function within GWLF was used to estimated loads and USLE equation for agriculture areas. Rating curve (power function) is used for estimating stream channel erosion. Planning level model only. Model should be revised to include more land uses and directly account for BMPs. Contact for the model: Penn State - Barry Evans.

2. Load Generation
   For load generation, Dr. Traver recommends using hydrologic analysis of both rainfall and flow. If assumption that all runoff occurs from impervious areas (urban areas only) is valid, only rainfall analysis is necessary. Otherwise, continuous rainfall-runoff simulation is recommended.

   Build-up/wash-off can be used for pollutant modeling from urban land uses, but Dr. Traver warned that any model using a build-up/wash-off function must be carefully calibrated if results are to be valuable.

3. Load Control
   In the DRBC study, the GWLF and AVGWLF models do not allow for BMPs to be directly modeled. In order to incorporate BMPs, Dr. Traver adjusted Curve Numbers downward, to account for infiltrated runoff from outside calculations of BMP performance. Dr. Traver believes that hydrologic controls are the most robust and quantifiable method to perform load control. His BMPs are designed to capture and infiltrate as much runoff as possible, with the assumption that transport through the soil

effectively removes pollutants (with the exception of chlorides). Dr. Traver has consistently found that percolation tests grossly overestimate infiltration capacity (and subsequent pollutant removal) and actually the surface layer of the basin is what determines the infiltration rate, not the amended soils underneath.

Treatment trains - address from hydrologic view point. Percent removals in series would need to be adjusted downward for each downstream facility. He is not sure how effluent quality would be applied - limits would need to be tested. Don't believe the data are available yet.

4. BMP Design

All sites on campus were retrofits, so space availability was fixed. Sizing was typically based on cost-effectiveness. The 2-year storm is often used because this is the storm that is required for geomorphologic analysis to minimize stream channel erosion. However, this effectively over-controls the small storms and under-controls the big storms. He helped develop design criteria for the State of Pennsylvania and came up with two control guidance for stormwater management - 1) Control Guidance 2: based on water balance must capture 1/2" and infiltrate to match pre-development base flows, on average 2) for water quality: all runoff up to one-inch must be infiltrated or evaporated (this is to control the first flush, which Traver believes works for small areas rather than big areas). He mentioned a study that found that a 1" design would capture about 90% of the pollutant load. Curve number method is still used in Pennsylvania and using this method there is no runoff from grassed areas for the first 1/2 inch, so they bumped up the original first 1-inch to 1.5 inches as to treat some of the runoff from grassed areas and as a safety factor. Therefore, currently the recommendation is 1.5" for the BMP design manual, but he states that 1" is probably sufficient. For stream channel protection, higher volumes are recommended (extended detention). Currently, these are not State criteria.

In order to perform his hydrologic analyses for BMP design, Dr. Traver has incorporated both SWMM-5 and HEC-HMS (uses because it is free) and recommends both as equal. His BMPs are designed to capture between 80-90% of the annual runoff volume. One - acre watershed (grassed area and paved area) draining to bioinfiltration traffic island. Modeled very successfully using Greene-Ampt, curve numbers, synthetic unit hydrograph, and kinematic wave. Noted a cyclic change in infiltration rates - likely due to worms, temperature, plants, ET, soil particles, etc. March lowest infiltration rate and October the highest - happens every year. Infiltration rates vary between 0.25" and 0.5".

Porous concrete site - infiltration rate (0.5-2 in/hr) is a function of depth and temperature (e.g., storm in March took 4-days to empty the bed; same size storm in April took 2-days). This site is wide (~40') so they don't observe the effects of side walls on infiltration - the percolation tests did not accurately predict the infiltration rates (result: ~8 in/hr). However, the infiltration trench which is not far from the porous concrete site, is performing at about 8 in/hr - presumably due to the effects of side walls. Modeling these processes in HEC-HMS has been done by putting in diversions and using rating curves.

Snowmelt: porous concrete site - no freezing on the surface. Bioinfiltration traffic island is a storage location for snow, so not a lot of studying of the snowmelt process.

Summary: Dr. Traver believes that capturing runoff and infiltrating it is the best way to ensure pollutant removal, as BMP modeling on the watershed scale is vague and land use data for generic land use types isn't usually applicable for specific sites. Hydrologic models are also more robust and easily calibrated, allowing the user to get better estimates of runoff than of pollutant removals through build/up wash off , variable source area, or any other type of pollutant buildup modeling. Path and timing of runoff are important processes that often ignored in hydrologic evaluations.

John Sansalone, Ph.D., PE.
Professor, Civil and Environmental Engineering
University of Florida
Interviewed on: April, 5 2005 at 9:00 AM PST.

1. Summary of Research
   Dr. Sansalone is currently in his 3rd year of research in the Lake Tahoe Basin where he has been compiling a snowmelt quality database. He has worked to develop relationships between hydrology and pollutant transport processes so that hydrologic parameters can be used a surrogates to water quality. He has two new articles submitted to the Journal of Environmental Engineering that describe this work.

   High concentrations of phosphorus have been observed from snowmelt sites in Lake Tahoe. Monitored sites include primarily paved areas within residential, commercial, and highway land uses. Paved areas were chosen because they present the highest potential for pollutant transport. Concentrations by particle size have been determined. High concentrations of TSS (~200 - 9000 mg/L), COD (~50 -1000s mg/L) and PO4 have been observed. While much of the pollutant mass is bound to larger material that probably doesn't make it to the Lake, much of it is bound to finer settleable particles (25-50 um range) as well as the suspended particles that do make it to the Lake.

2. Load Generation
   John agrees that fine particulate matter must be the focus of any research on clarity. Fine particulates sizes < 50 um are transported to the lake and < 20 um stay suspended. Prefer a number-based or volume-based analysis rather than mass-based analyses because this provides information on clarity (turbidity), potential for natural C/F, transport, and gravimetric mass can be back calculated. Turbidity could be more effectively used as a surrogate for suspended sediment concentration using these particle-based analyses.

   Need better characterization of runoff before any reliable estimate of loads to the Lake. Land use and season can be used as a reasonable surrogate for particle generation (no./mL or cc/mL) with better characterization data on particle number and size. Empirical correlation is more practical for planning, but from a research perspective.

   Nutrient correlation to particles for phosphorus, but dissolved fraction (i.e., ortho-phosphate) is also important. Snowmelt research has shown high O-P (up 0.5 mg/L) and sulfate.

   Continuous simulation or event-based, depending on design standard, however continuous simulation is more appropriate particularly when a good relation between hydrologic parameters and water quality parameters has been developed.

3. Load Control
   By using surrogates for loads and fundamental measurements of particles (i.e., correlations between particle number, turbidity, TSS mass, land use, etc.) one can estimate load reductions using volumetric approaches. A load monitoring program can

be used to collect a statistically defensible database and then pollutant loads can be estimated using hydrologic analyses. BMP performance can also be based on hydrologic and/or fundamental transport mechanisms given an understanding of the relationship between flow and load characteristics.

Filters and coagulation/flocculation systems seem appropriate for treating fine particulates. However, engineered C/F is cautioned because of receiving water sensitivity/toxicity issues. The question becomes, what is the constitutive relationship in terms of removal efficiency between hydrologic and water quality load characteristics to target a given effluent concentration or load reduction. Fundamental principles, such as 1st-order transport through a filter (or pore space head loss models, e.g., Kozeny-Carmen) to predict what the effluent characteristics will be. Or representative BMPs may be used. Percent removal should not be used without an effluent value.

Treatment trains can be predicted by using a combination of analytical and empirical observations and equations.

4. BMP Design

The decision of whether to have volumetric or flow-based criteria should be based on transport and treat-ability for the pollutants of concern. For particulates, a first flush is common because fine particles are mass-limited (the pollutograph drops faster than the hydrograph), while for fine particulates and dissolved pollutants a first flush is not as common because of a flow-limited situation where pollutant mass is continually being supplied throughout the storm. Volume-based criteria should be chosen if first flush, otherwise, flow-based criteria may be more appropriate.

If a water quality volume (WQV) is the used as the standard for design, a careful frequency analysis of the distribution of storms in time (intensity-duration) with loads transported (TSS mass as a function of volume) to determine whether mass-limited or flow-limited transport mechanisms are occurring.

Snowmelt storage and treatment practices should be encouraged, as well as effective pavement cleaning after snow melts and before the first rainfall event. Particulates will be abraded to smaller sizes that may be more easily transported.

Summary: Better physical-chemical-hydrologic characterization of runoff quality that relates hydrologic parameters to water quality is needed before pollutant loads can be reasonably estimated. For fine particulates, it is more useful to have concentrations in terms of particle number or particle volume rather than mass because these measurements allow for a direct relation to clarity (i.e., turbidity). Reasonable stormwater BMPs for fine particulates and nutrients are C/F and engineered/maintainable unit operations, but upstream volumetric control is needed for pre-treatment and to meter flows to these devices. Effluent quality can be used for BMP performance estimates, but physically-based equations (e.g., 1st order kinetics) can also be used in many circumstances for providing a basis for predicting performance. Operations and maintenance is as critical as the BMP type selected.

Michael Barrett, Ph.D.
Center for Research in Water Resources
University of Texas, Austin
Interviewed on: April, 5 2005 at 11:00 AM PST.

1. Summary of Research
   Dr. Barrett's research interests are focused on the quality, impacts, and mitigation of urban, agricultural, and construction site stormwater runoff and he has conducted numerous studies nationwide in this area. These projects involved the statistical analysis of water quality data, the evaluation of structural and nonstructural best management practices, and the development of watershed based stormwater management plans. During the last three years, Dr. Barrett has participated in stormwater projects in Texas, California, Arizona, and Oregon, including the Caltrans BMP retrofit feasibility study of 39 structural BMPs.

2. Load Generation
   Mike recommends a GIS approach for watershed level studies (weighted-flow accumulation). Event models are extremely data intensive and difficult to calibrate. The lack of sufficient input data into models such as SWMM often require averages or approximations to be used anyway, so there appears to be little benefit from using more complex approaches. Mike recommends watershed modeling on an annual runoff and annual load basis. Land use-based loading estimates can be used with annual rainfall to predict annual loads. However, Mike recommends impervious surfaces be used as the surrogate for pollutant loads rather than land use alone. Furthermore, channel and bank erosion must be included in any pollutant load estimate.

   Distributed annual rainfall coverage (e.g., PRSM) should be used to account for spatial variability. An annual runoff coefficient per land use can be calibrated using water quality data. Regression of imperviousness and pollutant concentration for each land use type can be used to have more variable EMC values.

3. Load Control
   Negative values can be used to account for BMPs in the weighted-flow accumulation method used for the load generation. Treatment trains are problematic and are not all that common. Mike is a believer that upstream BMPs do not necessarily reduce ultimate loads downstream; they just reduce the maintenance frequency of downstream BMPs. Monitoring at intermediate portions of a treatment trains (e.g., detention upstream of a sand filter) is not often conducted. BMP modeling would be based on empirical data, so only the combined treatment would be modeled. Percent reduction would be applied only to the fraction captured, which is based on the regulatory design criteria.

   Mike's experience with nutrients and fine sediments indicate that conventional treatment practices are not effective at removing concentrations, but some reductions in loads may be observed due to infiltration. Mike mentioned that Caltrans BMP monitoring data indicate no removals for nutrients, which is why Caltrans' are looking at placing activated alumina on roadsides.

Volume losses in BMP studies are difficult to assess, but should be accounted for when modeling BMPs.

4. BMP Design
   Except extended detention ponds, Mike believes bigger is better, but does understand that there is a point of diminishing returns for sizing BMPs (i.e., the majority of runoff should be treated without treating 100%). The Texas Edwards Aquifer Rules, which cover a portion of the City of Austin, require a reduction of 80% of the increase in TSS associated with new development. The City of Austin has its own separate requirement which is a sand filter or equivalent treatment. So the more effective a BMP is at removing TSS the smaller it needs to be (in terms of percent capture) to meet the reduction standard. Mike believes that a percent runoff capture on an annual average basis is a reasonable approach for developing design standards. More complicated approaches are not recommended because of variable levels of expertise among people designing and reviewing BMP projects and the difficulty in approving. In the City of Austin, extended detention basins are not allowed, but any other BMP must be a sand filter or equivalent. No credit is given for treatment trains in the City.

Summary: Pollutant load modeling using a Simple Method approach and utilizing GIS software is an appropriate strategy for watershed-scale modeling. Annual average volume and load calculations are sufficient for most analyses and the use of more sophisticated modeling methods, such as continuous simulations are often too data intensive and unnecessarily complex for the level of uncertainty in the input parameters. While he does not have much experience in modeling BMP performance, the use of percent removals is appropriate if enough data are available to support the performance claim. Design standards based on percent capture are adequate and appropriate, but using TSS reduction standard in addition to percent capture will provide an incentive for BMP designers to choose BMPs that provide higher levels of treatment for particulates.

Ben Urbonas, P.E.
Urban Drainage and Flood Control District
Denver, Colorado
Interviewed on: April, 6 2005 at 12:00 PM PST.

1. Summary of Research
   Ben Urbonas is the manager of the master planning program for the Urban Drainage and Flood Control District (UDFCD). He has extensive experience in BMP design, performance monitoring, and evaluation. Much of his research has focused on design standards as he is one of the primary authors of the UDFCD Urban Storm Drainage Criteria Manual. He has developed an approach for evaluating and designing sand filters that is based on hydraulic capacity of the filter media, which, in turn, is a function of the total suspended solids removed by the filter. Some of Ben's recent research on stream erosion and degradation has led him to advocate "full spectrum detention", which suggests that the full range of pre-development peak flow rates from the smallest runoff event to a 2-year event, and to less frequent events, possibly up to the 100-year storms should be matched for post-development.

2. Load Generation
   Simple spreadsheet models are probably just as accurate as more complex models for estimating loads because we don't understand the transport processes well enough. Ben recommends evaluating the losses and gains in the conveyance system - upstream areas tend to lose volumes and loads, while downstream areas tend to gain volumes and loads. For example, background groundwater concentrations of phosphorus are often higher than surface water concentrations, so gaining streams can, under those conditions, become a significant source of phosphorus. In-stream sources of sediment and nutrients (e.g., waterfowl) should also be characterized, especially during high flows.

3. Load Control
   Ben recommends an effluent quality approach rather than percent removal for estimating treatment in BMPs. The grain size and chemical characteristics of BMP media (e.g., sand filters, porous pavements, infiltration basins, etc.) should be evaluated. For example, the use of iron coatings on sand particles in a filter bed maybe an effective means of removing dissolved phosphorus. Initially, modeling may requires the use of existing effluent quality data (e.g., ASCE/EPA BMP database) until local BMP performance data become available.

4. BMP Design
   With respect to BMP design, Ben recommends a tiered approach where you first reduce volumes to the maximum extent practicable (MEP) by reducing directly connected impervious areas and using distributed infiltration and storage devices. The remaining portion of the water quality control volume (WQCV) should be captured and detained as to match pre-development peak flows such that full-spectrum detention is accomplished. This is needed to mitigate hydrologic changes that occur from urbanization.

Summary: Ben believes loads can be adequately estimating using simple empirical methods provided enough pollutant source characterization data are available. It is important to assess in-stream contributions and identify stream segments that are losing or gaining volumes to/from the subsurface (interflow is often a major contributor to nutrient loads). BMPs can be adequately modeled using effluent quality data from similarly designed BMPs, but local data should be used to the maximum extent possible. The design and implementation of BMPs should follow a tiered approach where volumes are first reduced to the maximum extent practicable to mitigate hydrologic changes from urbanization and then the remaining WQCV is detained/retained such that the full range of predevelopment peak flows are reasonably matched to reduce flooding damages downstream..

Larry Roesner, Ph.D.
University of Colorado
Fort Collins, Colorado
Interviewed on: April, 6 2005 at 1:00 PM PST.

1. Summary of Research
   Dr. Roesner has extensive experience in water resources and water quality engineering and management. He is a nationally recognized expert in the development and application of hydrologic, hydraulic, and water quality simulation models. He is a principal developer of the Corps of Engineers model STORM, a simplified urban storm water management model, and EPA's SWMM EXTRAN model, a sophisticated flow-routing model for urban drainage systems. He also has considerable experience with time series analysis of hydrologic records and has developed stochastic models of monthly precipitation and runoff. Another of Dr. Roesner's areas of specialization is water quality simulation of surface water bodies. Dr. Roesner is the principal author of QUAL-II, a stream water quality model developed for USEPA which simulates 11 water quality parameters. He has conducted a number of US EPA-sponsored workshops on the application of QUAL-II and has experience with model applications throughout the United States and in Canada. QUAL-II has been used extensively for wasteload allocation studies throughout the United States.

2. Load Generation
   Load generation estimation is difficult, but recommends the use of a simple continuous simulation model, such as Quick STORM or STORM, that includes storage for predicting volumes. This must be calibrated to ensure the average annual volumes are accurate. Load contributions should then be based on land use EMCs and the predicted flow volumes. Larry does not recommend mean annual estimates to be used because storage is not adequately accounted for a sequence of storms. If the runoff coefficient does not seem appropriate for the site, then a TR-55 method or other method that takes into account soil moisture may be adequate, but he doesn't think it should be made any more complicated than that.

3. Load Control
   For load control, Larry also recommends the use of continuous simulation to determine the annual volume that is captured or bypassed by the BMP. Bypassed volume should receive the raw area-weighted EMC, while the captured volume should receive the percent reduction (or effluent quality). However, residence time should be factored in such that the percent removal is adjusted according to the time in the BMPs. STORM is simpler than SWMM because it does not route flows, but is an appropriate alternative when runoff is detained for long periods of time. He doesn't have a real good idea of how to simulate treatment trains.

4. BMP Design
   If you design a BMP to control large storms, such as the 10-year or even a 2-year, such that the volume drains within 24-hours, virtually no control will be provided for the smaller storms. Therefore, Larry recommends combined flood control and treatment

control systems that control multiple design storms from the 2-year all the way up to the 100-year. The design approach would be to take a typical development area, perform a continuous simulation of runoff (using SWMM or other model), and develop a flow-frequency curve for pre- and post-development with controls. BMPs should be first designed to match the 10-year and 100-year peaks, and somewhere between the 1-2 year peaks based on local analysis, to pre-development flows. In addition, a BMP equivalent to detention with a 40-hour drawdown for the WQCV (e.g., 80th percentile) should be required. This may extend the duration of small flows, which may contribute to erosion in sandy soils and may contribute to phosphorus loadings through stream bed erosion, but more cohesive soils should not erode. Therefore, he recommends matching the flow-duration curve in sandy soils, but if they are not, then matching the flow-frequency curve is adequate.

Summary: Larry advocates the use of continuous simulations for estimating runoff volumes to and through stormwater BMPs. SWMM is probably too complicated for large scale projects, but STORM is appropriate, especially when flow-routing is not a significant concern. After annual runoff volumes are estimated using a continuous simulation approach, land use based EMCs can be used to predict loads. Treatment in BMPs should be based on the volume captured and bypassed (determined from the continuous simulation) such that the percent removals are only applied to the captured volume. Hydraulic retention time can be used to adjust percent removal values in BMPs.

Robert Pitt, P.E., Ph.D.
University of Alabama
Tuscaloosa, AL
Interviewed on: April, 6 2005 at 4:00 PM PST.

1. <u>Summary of Research</u>
   Dr. Pitt has been involved with stormwater management research for more than 30 years, examining receiving water problems, pollutant sources, and control technologies. He is one of the primary developers of the Source Loading and Management Model (SLAMM), a planning-level tool for predicting urban runoff quality and stormwater treatment. Recent research has included investigations of metals transport and control in alternative urban drainage systems, urban soil modifications that enhance drainage and pollutant control, the identification of inappropriate discharges to storm drainage, and the compilation and evaluation of nationwide data obtained during the stormwater discharge permit program. He has done some research on snowmelt quality in Wisconsin and Canada and has noted significant impacts of winter salts on soil structure and chemistry (e.g., sodium adsorption ratio and cation exchange capacity) that affects the pollutant removals in bioretention and infiltration devices.

2. <u>Load Generation</u>
   First off, a detailed assessment of the geographical uniqueness of the Lake Tahoe Basin should be conducted before any model or methodology for load generation is selected. Existing water quality and flow data should be compiled and analyzed to the maximum extent possible. Even though Bob admits he has a bias towards the use of SLAMM, he strongly recommends its use because it was specifically designed for this type of load generation and control analysis and has been successfully applied elsewhere (e.g., Wisconsin). As compared to hydrology models that focus on drainage design analysis (peak flow; large infrequent storm events), the hydrologic component of SLAMM is unique because it was specifically developed for mass loading predictions (event volumes; small frequent storm events). As compared to drainage design, many micro-scale factors must be considered to accurately predict the hydrology for the majority of mass loading events. For example, the type of impervious surfaces (e.g., flat roofs versus pitched roofs; smooth pavement versus rough pavement) and disturbed urban soils (e.g., soil structure) are important factors for small storm event, but may be reasonably neglected for drainage design.

   Continuous simulations (30-50 years) are critical in order to account for the seasonal component, especially with regard to nutrient loadings. SLAMM does not currently have a snowmelt component, but Dr. Pitt notes that snowmelt quality and quantity are extremely important factors that must be considered for Tahoe because of the potential impacts of traction sands and salts on the loadings of fine sediment and the treatability of pollutants in soils. SLAMM simulates volumes and loads on a storm-by-storm basis using a continuous rainfall record. The spatial scale can vary significantly, but through the use of batch processing can estimate large watersheds. Particle-size distributions can be simulated in the SLAMM model during sediment transport and the treatment in several different types of BMPs. Sources of pollutants from streams are not directly modeled in SLAMM, but by interfacing with a hydrologic model such as HSPF this can be made possible, as well as characterizing flow-duration curves. SLAMM is not designed for receiving water impact assessment; it is designed for mass loading predictions to the receiving waters.

Dry and wet atmospheric deposition is a source that should be considered, but only about 10-20% of the pollutants (e.g., nitrogen) that is deposited on impervious surfaces will show up in the runoff. Direct deposition on the Lake would obviously be 100% and should be quantified through monitoring. SLAMM does not really have a component to account for atmospheric deposition, but does account for it with respect to roof runoff, but this also includes the contribution from roofing materials.

3. Load Control
   SLAMM provides many different options for simulating treatment, such as source controls, inlet controls, in-stream controls, and end-of-pipe practices. Physical sedimentation is predicted in both the conveyance system as well as in treatment controls. SLAMM can simulate bioretention practices, infiltration and evapotranspiration, as well as public works practices, proprietary devices (e.g., magic swirly devices), and porous pavement. Recent developments have included the simulation of sediment transport in swales that accounts for particle size, grass conditions, and channel dimensions. Networks and treatment trains are easily simulated within the model and both dissolved and particulate pollutants are simulated. The incorporation of filter processes has complicated the model some because ion exchange and adsorption processes require specific classes of pollutants to be simulated rather than just solid particles. Green roofs and detailed hydraulic routing in drainage systems are not simulated in SLAMM. Some work has been done to integrate EXTRAN in SWMM 4, but this work was not completed.

   Some of the data requirements include land use characteristics, rainfall, and soil information. Obviously, site-specific data must be collected for calibration, but existing data may be adequate. For verification purposes, some field monitoring must be conducted.

4. BMP Design
   Treatment train approaches must be emphasized, both on small and large scales, because a single design standard is not appropriate for every type of treatment control, particularly when these controls are in series. The approach should be to first modify the distribution of runoff volumes by eliminating small storm runoff (up to about the median storm event depth) through infiltration, depending on the local soils resources and landscaping options at a particular site. This may effectively remove between 1/4" and 1/2" of runoff. The majority of pollutant discharges likely occur for storms less than about 1.25", so treatment of storms up to about this size is probably all that is needed. Therefore, the runoff that cannot be removed via infiltration and evapotranspiration must be treated in some sort of control. From a cost-benefit perspective wet ponds are difficult to beat in terms of the amount of volume that can be treated. In residential areas, most of the runoff probably can be treated with distributed controls such as swales, but in commercial areas

with high impervious areas a more centralized control such as a wet pond may be necessary. For higher volumes and flows (above about 1.25"), dry ponds are appropriate for stream protection. From this perspective, the flow-durations above some critical flow probably should be matched to predevelopment conditions. Finally, flood protection should be provided with conventional drainage design approaches. Also, critical source area controls are important, such as commercial and industrial areas to treat at critical point locations before more polluted runoff is mixed with runoff from surrounding areas. It is rarely possible to optimize BMP design, so it is important to evaluate the design to determine if, at a minimum, the objectives are being met.

Summary: The approaches and assumptions typically applied in drainage design are not appropriate for mass loading estimation, which is driven by small frequent storm events. Therefore the use of many of the commonly used hydrologic models for water quality assessments is discouraged. Dr. Pitt strongly advocates the use of SLAMM for load generation and control estimation. This model is a continuous simulation model that uses a build-up / wash-off function for estimating pollutant loads. Treatment is simulated using primarily unit operations and processes functions such as sediment transport, settling, and adsorption. Many different types of BMPs can currently be simulated using SLAMM, including bioretention cells, infiltration ponds, swales, detention ponds, public works controls, and proprietary devices. For BMP design, Dr. Pitt recommends a tiered approach where you first try to 1) eliminate the small storms from the runoff probability frequency curve, then treat the remaining runoff up to some water quality design volume (e.g., 1-2"), then 2) provide channel protection using a flow-duration approach such that post-development matches the flow-duration curve above some critical flow, and finally 3) provide flood protection with conventional conveyance system design. Also, critical source areas should be identified and treated to the maximum extent possible using decentralized controls (e.g., MCTT, inlet devices, etc.) to avoid mixing dirty water with clean water.

Roger Bannerman
Wisconsin Department of Natural Resources
Madison, Wisconsin
Interviewed at 11 AM, April 11, 2005

1. Summary of Research
   Roger Bannerman's research has focused on practical BMP testing and modeling to support the implementation of the State of Wisconsin's non-point source control program. Of particular interest is the work conducted by Roger regarding lake restoration efforts and phosphorus reductions.

2. Load Generation
   The SLAMM model developed by Bob Pitt is 1983 has been continuously refined by Roger and others based on data collected in Wisconsin and elsewhere. Roger has used this model to estimate loads to receiving waters, including lakes in Wisconsin which are affected generally by phosphorus loads. Originally he developed nomographs for ease of implementation, but there is increasing demand and comfort with using the model directly. For example, the City of Madison (population 200,000) has an engineer who has set up SLAMM for entire city so that any control that might be considered can be evaluated with relative ease.

   Experience with SLAMM indicates that often can get within 10% of runoff volume, and within about 30% for phosphorus load. He feels small storm hydrology module in SLAMM is superior to TR-55 SCS Curve Number approach which ideally is more suitable to larger events.

3. Load Control
   Experience with phosphorus control indicates that the most promising technologies are infiltration, filtration, or enhanced settling. Detention alone is not adequate. Roger uses SLAMM model to assess load reductions from source and treatment controls, including effectiveness of programs to limit nutrient applications, street sweeping, and a host of treatment type controls. Currently rain gardens are popular and considered effective, especially in encouraging infiltration.

   Roger states that biggest problem is public acceptance to costs involved ("sticker shock"). The current stormwater utility charge in the City of Madison is $36/yr per household.

4. BMP Design
   Four years ago, state adopted a new development design standard in Wisconsin is to reduce post-development sediment by 80%. On October 2, 2004 the state passed a law requiring that new developments infiltrate up to 90% of the post-development runoff from residential developments and up to 60% of the runoff from commercial developments. Where soils limit infiltration, rain gardens or swales that incorporate filtration utilizing amended soils and an underdrain are encouraged.

For lakes where emphasis in on retrofitting, the goal is set by the individual watershed plans, and lead agency can track progress using SLAMM towards that goal for each new control that is implemented. There is no need for a uniform standard which is difficult to implement in retrofit situations.

With respect to BMP design, SLAMM was designed originally as planning tool, but recent enhancements have been made it more useful as design aid.

D.2 Agency Interviews

Twelve agencies in various parts of the United States were contacted to gather information about their pollutant load and load reduction estimation methodologies. These agencies were selected based on their engagement in active stormwater-related TMDL or other water quality improvement programs. Additional information was collected about TMDL program structure and management to provide a context for the types of estimates each agency performed. The program interviews are listed in Table D.2, and summaries of each interview are provided.

Table D.2 – Program Interviews

Agency	Interviewee(s)	Position
Chesapeake Bay Program – EPA	Rich Batiuk	Asst. Director for Science Environmental Scientist
Florida Department of Environmental Protection	Jan Mandrup-Poulsen Douglas Gilbert Eric Livingston	Administrator Environmental Manager Chief, Watershed Mgmt Program
Kansas Department of Health and Environment	Tom Stiles	Chief, Bureau of Water
Lake Champlain Basin Program	Eric Smeltzer	Environmental Scientist
Maine Department of Environmental Protection	David Halliwell	Maine Lakes TMDL Program Manager
Maryland Department of Environmental Protection	Elaine Dietz	TMDL Outreach Coordinator
Minnesota Pollution Control Agency	Greg Johnson	Senior Hydrologist
New York Department of Environmental Conservation	Ron Entringer	Chief, Source Protection Section
Ohio Environmental Protection Agency	Trinka Mount	TMDL Coordinator
South Carolina Department of Health and Environmental Control	Kathy Stecker	Section Manager of Watersheds and Planning
Texas Natural Resource Conservation Commission	Ward Ling	Project Manager
Wisconsin Department of Natural Resources	Jim Baumann	Special Assistant to Director of Watershed Management

Rich Batiuk
Assistant Director for Science
EPA – Chesapeake Bay Program
Interviewed on April 4, 2005, (410) 267-5731

1. Describe how the program works / what are the key components of the program?
   Formed in 1983. This is not an EPA program – rather, it is a partnership among state, federal and academic groups. The executive council meets annually to establish the direction of the program.

   Website Information:
   The website has a complete list of partners, chart of organizational structure, and calendar of all meetings. This program is tremendously large, with layers of management and different branches. It includes a lot of research activities and political involvement.

   The need for a 40% reduction in N and P loads were established in 1987. A cap on these nutrients was allocated to 10 tributary basins in 1992. The states then developed strategies for meeting their load reductions. In 2000, the Chesapeake Bay Program Partners committed to going beyond the cap allocations and facilitate local stakeholder-based implementation plans ("tributary strategies"). A regulatory TMDL will be put in place by 2011 if water quality is not restored by 2010.

2. Who are your primary stakeholders?
   The original states were: Maryland, Virginia, Pennsylvania and Washington, D.C. Then three more headwater states were added: West Virginia, New York and Delaware. There 26 federal agencies, states, local governments, watershed associations.

3. How is the program managed? One agency, several agencies, oversight group?
   The program is managed by the Chesapeake Bay Commission, with representation from the three original states (MD, VA and PN). There are 500 to 600 individuals on all of the various committees. It is staffed at the technical policy level by the EPA – Annapolis office. There are federal partners in this office, as well as state/university colleagues. Public has the ultimate oversight, though EPA is generally the federal level leader.

   Management is broken into two levels: political and implementation. The political side is managed by a Chesapeake Executive Council, which the Pennsylvania governor currently chairs. The chair rotates every two years. The EPA chairs the implementation subcommittee, although management is generally through consensus.

4. How is the program funded?
   $20-30 million annually is through an appropriation under the Clean Water Act- a small part of this is used to run the program, and $3-4 million annually is given to the states for implementation. The partners provide direction on spending the remainder of the money; this is unique among TMDL programs. A budget steering subcommittee handles this.

An additional $200-300 million annually is spent through the 26 federal agencies. State and local partners contribute as well; all spending totals about $500-600 million over several years.

5. <u>How is pollutant loading determined?</u>
   The process for determining cap load allocations (annual loads) had two parts: the science got close on determining how much load could be reduced, then they had to close the gap politically. State representatives at a high level got together in a room and negotiated who would take what loads.

   Two methods of determining numerical loads – direct monitoring and modeling. They monitor major rivers like the Susquehanna (9 major rivers altogether).

   They have an HSPF-based model of the entire Chesapeake Bay watershed – 64,000 square miles. It is essentially a large accounting spreadsheet that includes land development and rainfall. They use a recent 10-year set of hourly hydrology and determine 10-year average loads, although they have data for a total of 17 years. They are looking to do more near-time estimates by using recent hydrology; the primary difficulty is getting the data from the responsible agencies in a timely manner. The watershed model has 94 segments.

   See website for more information on modeling, Phase 4.3 documentation for more information on pollutant loadings by land use.

6. <u>How are BMP efficiencies determined? Individual and treatment trains.</u>
   They have a list of 40 BMPs that they are trying to determine the efficiencies for, considering different storms and different implementation practices. They are in the process of putting together better documentation than is on website. BMPs can be added to their watershed model, which they update every year with new information on newly installed BMPs.

   They have a "tributary strategy workgroup" that developed numbers for BMP efficiencies. Once they have agreement, they sign off on these efficiencies, using a consensus-based decision-making process. See the document "Chesapeake Bay Watershed Model Application and Calculation of Nutrient and Sediment Loadings: Appendix H – Tracking Best Management Practice Nutrient Reductions in the Chesapeake Bay Program".

7. <u>How do you handle retrofits of existing older projects? Private property BMPs?</u>
   They don't deal with this because it's too small of a scale. They suggested that one would have to make an assumption for BMP efficiency or land use.

8. <u>What aspects of your program work well and don't work well?</u>
   Positive: They use group agreement, and policy people at a high-enough level are involved, so they are able to actually make decisions. They went through a 2 year process of meetings, with most of the work done between meetings and actual decisions

made at meetings, so work progressed. Another positive aspect of their program was building cap load allocations into state water quality planning regulations. And use of a basin-wide permitting strategy.

Negative: They have found that there are some drawbacks to consensus-based decisions because they usually only reach lowest common denominator. They are supposed to have a basin-wide TMDL by 2010, but they haven't gotten there yet. And they find that states have a hard time looking long-term and developing specific implementation plans.

9. <u>Is there a feedback loop, whereby the program can be improved?</u>
   They have a 5-year re-evaluation process. They 'lock down' their program for about 5 years, then update it all at once, then 'lock it down' again. The update consists of applying the latest science, updating BMP efficiencies, and implementing any modeling changes.

   They also update the model annually with land use changes and added BMPs (large-scale) and check whether water quality has improved. This is part of their plan to move to an annual public accounting of how well projects are working.

10. <u>Do you work with pollutant trading/offsets/informal banking?</u>
    Yes, this is starting to be built into state programs. They follow the EPA trading guidelines.

11. <u>Can you recommend anyone else/any other agency to contact?</u>
    Long Island Sound TMDL, although they are only looking at point sources.

Jan Mandrup-Poulsen – Administrator, (850) 245-8448
Douglas Gilbert – Environmental Manager, (850) 245-8450
Eric Livingston – Chief, Watershed Management Program (850) 245-8430
Florida Department of Environmental Protection
Interviewed March 28 – 31.

1. Describe how the program works / what are the key components of the program?
   To streamline the TMDL program, DEP adopted a five-year cycle that divides Florida into five groups of surface water basins in which different activities take place each year; the cycle is reiterated continuously to evaluate the success of clean-up efforts, refine water quality protection strategies, and account for the changes brought about by Florida's rapid growth and development. Activities include preliminary basin assessments; identification of pollutant-impaired waters; targeted water quality monitoring and data analysis; TMDL development and adoption; basin planning with local stakeholders to establish the actions necessary to reduce pollution; and implementation through regulatory actions, funding, pollution prevention strategies, and other measures. (FDEP, 2005)

   Dividing the state this way has allowed DEP efficiently to manage different activities in each of the water body groupings leading to the development and, ultimately, implementation of TMDLs throughout Florida. The general sequence of the five-year cycle is as follows:

   1) Preliminary basin assessment focusing on existing data.
   2) Strategic water quality monitoring to obtain additional detailed scientific evidence of water quality conditions and adoption of basin-specific verified lists of impaired waters.
   3) Data analysis and TMDL development and adoption where impairment exists.
   4) Development of a Basin Management Action Plan, in conjunction with local stakeholders, to allocate, among the local sources of pollution, reductions necessary to meet the TMDL.
   5) Implementation of the TMDL.
      (FDEP, 2005)

      - Chapter 62-303 of Florida's Administrative Code provides detailed guidance on identifying impaired waters
      - Florida has a significant public outreach program
        - Numerous public meetings have been held (partially because it's a large state)
        - They make an effort to get stakeholders involved
        - TMDLs are subject to public hearings before adoption
        - Collect data from numerous sources within basins- data collection standards have been specified in Rule 66
      - They characterize pollutant sources using GIS
      - They try to reward those who have been pro-active when it is time to allocate loads

    - E.g. they leave people with BMPs 'off the hook' until people without BMPs catch up

2. <u>Who are your primary stakeholders?</u>
   Pretty much everyone except small unincorporated municipalities, small farmers.

3. <u>How is the program managed? One agency, several agencies, oversight group?</u>
   Florida Dept. of Environmental Protection is the lead agency, with several bureaus that handle different aspects of the program. For example, there is a bureau that specifically collects water quality data and another that does program outreach. Surface water data is collected from sources such as counties, local labs and consulting firms.

4. <u>How is the program funded?</u>
   Some money comes from the State's General Revenues, but most comes from other sources:
   - EPA grant funds:
     - Section 106 of the Clean Water Act grant funds
     - Apply for separate grants through the 104 program
     - Section 319 non-point source grants
   - Trust funds
     - Water Quality Assurance Trust Fund
     - Land Acquisition Trust Fund

   FDEP has also proposed applying water quality protection fees to substances that directly or indirectly contribute to pollution, such as fertilizer, cement, asphalt and pesticides.

   Florida also has over 100 stormwater utilities, which provide a mechanism to implement MS4 projects.

   The Legislature may fund a common treatment, like lining a wastewater lagoon. They generally tackle items like that in big chunks because it's more efficient. Some projects, such as sewer retrofits in major cities, may be funded over 20 years.

5. <u>How is pollutant loading determined?</u>
   They use event mean concentrations by land use and hydrology to generate loads. The hierarchy for EMC data is 1) local data (from watershed management districts, silvaculture industry); 2) regional data; and 3) literature values. Local water quality data was very thin originally, but over the last 15 years has become much more readily available. Land use is aggregated into 10 categories and modeling is done at a fairly broad scale.

   Models used include the following:

   1) CDM's WMM, available from the Rouge River website. They took the math out of the model and put it into an Excel spreadsheet. They include an adjustment for directly connected impervious area, and therefore use an "effective rainfall".

2) Eutromod, from the North American Lake Society. Works ok for determining volumes and mass from watershed, but doesn't seem to provide a good fit to lake data.
3) Dr. Walker's suite of models called BATHTUB. No watershed loading, but uses a different set of equations that better model lake conditions. Only good for average annual conditions, not for seasonal or monthly use.
4) Occasionally develop their own algorithms where necessary to produce a good fit to lake data.
5) Follow up on hydrologic inputs

Modeling process:

- Calibrate model to current conditions
- Set land use back to historical conditions to determine undeveloped conditions
- Legislature wants to use the higher assimilative capacity, not lower historical conditions as target
- Using assimilative capacity is intended to leave a buffer for future growth (?)

6. How are BMP efficiencies determined? Individual and treatment trains.
Research is being done for both point and non-point sources, so they use values from on-going studies. Otherwise, they use values available from literature. They recognize that maintenance affects efficiencies, so maintenance is addressed as part of funding agreements. They do have active inspections with consequences for non-maintenance.

If they have a spatially disaggregated landscape model, they can pinpoint sources of pollutants; this helps with the implementation phase because you can locate most severe sources. For BMPs, they assume standard efficiencies from the EPA and add these to their model until they achieve their desired total reduction. They don't do this when they don't have a detailed model. They instead make an estimate outside of the model of how many BMPs are needed to meet load reduction goals. This process is part of development of the Basin Management Action Plan. As they are driven by lawsuit time constraints, they only infrequently do detailed modeling.

7. How do you handle retrofits of existing older projects? Private property BMPs?
Their stormwater permitting program has required that new construction implement BMPs since the mid-80s. In the TMDL process, areas with BMPs in place are given a break while areas without BMPs in place are required to get up to speed.

8. What aspects of your program work well and don't work well?
They are still in the first 5-year cycle, so they can't say how it all works. They are pretty happy with most of the program to date. The only concern is that the TMDL is not based on adequate data.

9. Is there a feedback loop, whereby the program can be improved?
Once the TMDL program is set, percent reduction targets are established. They then develop a Basin Management Action Plan (BMAP) which determines who will do what to achieve TMDLs. Many different stakeholders work together and jointly determine

this. The Legislature may step in and force those who don't want to participate to get involved.

There are two types of feedback: political and technical. Politically, if the TMDL is not acceptable to the stakeholders, it is challenged and often new information is provided that enables FDEP to re-visit the TMDL. Technically, every TMDL is on a five-year cycle for re-evaluation of water quality.

10. Do you work with pollutant trading/offsets/informal banking?
    There is a Pollutant Trading Advisory Group that is working on this process; it will probably be available within another year. They have not seen anyone do a really good job with this, but recommended contacting Idaho, Michigan, North Carolina and Connecticut for more information.

11. Can you recommend anyone else/any other agency to contact?
    Iowa has a data quality law
    Arizona followed Florida's lead in implementing a TMDL program

References

Florida Department of Environmental Protection, Division of Water Resource Management, February 2005. Florida's Total Maximum Daily Load Program: the First 5 Years – A Report to the Legislature and Governor.

Tom Stiles
Chief, Bureau of Water
Kansas Department of Health and Environment
Interviewed April 8, 2005, (785) 296-6170

A formal interview was not conducted with Mr. Stiles; he instead provided information on the Kansas DHE's method of applying flow duration curves to determine acceptability of load levels.

The Kansas Department of Health and Environment is under a court order to finish a large number of TMDLs in a relatively short amount of time. They needed a simple and quick method to establish TMDLs and meet their legal requirements, but they also wanted a method that recognized that load varies with flow. They found that using a flow duration curve methodology addressed these issues, and has the additional benefits of providing a visual reference that laypersons can readily interpret. The EPA has endorsed this method for development of TMDLs.

Daily flow data is needed to apply this method. Kansas has a pretty good density of USGS streamgages, and they have also extrapolated data records using simple ratios of drainage areas. Once a flow duration curve has been developed, it is converted to a load duration curve by multiplying the flows by the water quality concentration standard and a conversion factor. More recently, they have used concentration duration curves because concentrations are more useful to them than loads for purposes of regulation. Individual water quality samples are plotted on the load or concentration duration curve versus the average daily flow on the day they were taken. If they plot below the curve, water quality is within compliance, and if they plot above the curve, water quality is out of compliance. They feel comfortable applying this methodology to watersheds ranging from 50 to 100 square miles in area; they would not recommend it for very small or urbanized watersheds due to the flashy nature of flows from these areas.

Their implementation plans are non-specific, simply stating that a load reduction is needed, and actual implementation approach is deferred to the local level.

Eric Smeltzer
Environmental Scientist
Lake Champlain Basin Program
Interviewed April 8, 2005,(802) 241-3792

The interview with Mr. Smeltzer ranged over a number of topics, and did not follow the standard interview format. The interview is therefore summarized in a general text format.

They adopted a TMDL in 2002; this is a joint TMDL between Vermont and New York, though part of the lake lies within Quebec as well. The three governments came together (with the U.S. states getting an extra push from the federal government and the EPA) to adopt a P criteria for different parts of Lake Champlain. There were successful in getting agreements on targets between all three governments, even though each state/province already had its own water quality standards. This established an environment of cooperation.

No watershed modeling was performed as part of the Lake Champlain TMDL. The primary source of data was water quality monitoring at approximately 30 inflow points to the lake. They also developed land use coverage for the entire watershed and applied export coefficients to determine loads, but an emphasis was placed on the monitoring data.

Assignment of load allocations between the states of New York and Vermont took a long time, and was essentially a political process. They developed a spreadsheet model that assessed the economic implications of different load allocation schemes to aid in the decision-making process. Vermont and Quebec also negotiated load allocations, but it was a much simpler process because they based the required load reductions on the percentages of loads contributed to the lake by each entity. They highly recommend taking a simple, transparent approach to load allocations because it will save a tremendous amount of time and effort.

They continue to monitor lake inflows to assess compliance with the established water quality targets. Most non-point source P comes from dairies in Vermont and eroding streambanks. Currently, the state is focusing its efforts on stabilizing streambanks, but there is no way to estimate load reductions for this type of BMP. They therefore use other indicators of success (lake water quality monitoring) to monitor progress because they can't make a reasonable estimate of load reduction effectiveness.

Elaine Dietz
TMDL Outreach Coordinator
Maryland Department of Environmental Protection
Interviewed April 7, 2005, (410) 537-3667

1. <u>Describe how the program works / what are the key components of the program?</u>
   The state is divided into 5 areas; each area is analyzed on a 5-year cycle. The process begins with water quality monitoring. A 303d list is developed from this, along with a list of low, medium and high priority areas. "Water quality analyses" are then performed for these areas in order of priority. If the analyses indicate that the areas do not meet state water quality standards, a TMDL is performed. Maryland is not required to do implementation – they instead reference existing programs to provide the assurances that EPA requires. They are currently developing a guidance document for local governments, but it will not be prescriptive because of the overarching jurisdiction of the Chesapeake Bay Program.

2. <u>Who are your primary stakeholders?</u>
   Local governments – they developed a list of primary TMDL contacts at each city and county to get them on board early in the process. Also permitted dischargers, watershed organizations, other state agencies, soil conservation districts, and any other interested parties.

3. <u>How is the program managed? One agency, several agencies, oversight group?</u>
   The Maryland Department of Environmental Protection has sole authority.

4. <u>How is the program funded?</u>
   Both state and federal funds.

5. <u>How is pollutant loading determined?</u>
   Non-point source loadings are determined using the same data at the Chesapeake Bay Program.

6. <u>How are BMP efficiencies determined? Individual and treatment trains.</u>
   They are currently in the process of developing a list of BMP categories with associated pollutant removal efficiencies and hydrologic effects. Unfortunately this is still a draft document and is not available for release.

7. <u>How do you handle retrofits of existing older projects? Private property BMPs?</u>
   They treat these as new installations in terms of identifying efficiencies, but this is a very small part of their program.

8. <u>What aspects of your program work well and don't work well?</u>
   The outreach and coordination framework works well; they do a significant amount of stakeholder contact throughout the course of a project.

On the flip side, they have difficulty maintaining the expected pace of TMDL development due to funding and staffing constraints.

9. Is there a feedback loop, whereby the program can be improved?
   They get direct feedback from their stakeholders through the outreach program.

10. Do you work with pollutant trading/offsets/informal banking?
    They support the concept of pollutant trading, but haven't actually done this. They may do so in the future, and they would likely use a market-based approach. They have occasionally done offsets for wastewater treatment plants, and they have never dealt with banking.

11. Can you recommend anyone else/any other agency to contact?
    Not really.

David Halliwell
Maine Lakes TMDL Program Manager
Maine Department of Environmental Protection
Interviewed April 4, 2005, (207) 287-7649

1. Describe how the program works / what are the key components of the program?
   They believe that they have a very efficient program. They do 6 lake TMDLs per year, and as each takes two years to complete, they have 12 on-going at any one time. They have at least two years of monitoring data for each lake, looking at sediment and phosphorus. They take monthly samples the first year, and biweekly samples the second year.

   They follow the EPA's 12-point protocol on developing TMDLs.

2. Who are your primary stakeholders?
   Watershed residents – both season and year-round; lake association members; regional lake organizations (watershed districts); counties' soil and water conservation districts; NRCS office; municipalities.

3. How is the program managed? One agency, several agencies, oversight group?
   The Maine DEP Lake Assessment section runs the program, but they contract out most of the work through the Maine Association of Conservation Districts and review the draft reports.

4. How is the program funded?
   EPA 319 grants fund virtually all of the work.

5. How is pollutant loading determined?
   They use GIS land, soils and elevation coverage, but follow up in watershed of interest to get additional detail. For example, they check every property to determine its condition and the distance from lodging to the lake. Within each land use category, they have a high-medium-low coefficient that comes from Reckhow's work (Modeling Phosphorous Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients (EPA 440-5-80-011)). The median value is typically used, although the coefficient may be adjusted using professional judgment based on site conditions and BMPs in place. A numerical load value is then calculated for watershed sources, upstream lake sources and in-lake sources. This is compared to an assimilative capacity determined from criteria such as no algal blooms plus a buffer for future development. The resulting difference between current loading and assimilative capacity is the target reduction.

6. How are BMP efficiencies determined? Individual and treatment trains.
   No quantitative load reductions are currently calculated, although they are moving in that direction. Instead, general practices are recommended for a given watershed, such as fixing septic systems, upgrading roadways and encouragement of private property BMPs. They monitor lakes using a Secchi disk to determine whether water quality is improving.

7. How do you handle retrofits of existing older projects? Private property BMPs?
   Not applicable, as they don't determine quantitative BMP efficiencies.

8. What aspects of your program work well and don't work well?
   It is sometimes difficult to get stakeholders to participate, at the state and federal level.

9. Is there a feedback loop, whereby the program can be improved?
   They continuously modify the program as they learn. In the second phase, not yet implemented, they will check 5 years of continuously monitored data to determine whether they need to re-visit a lake.

10. Do you work with pollutant trading/offsets/informal banking?
    No

11. Can you recommend anyone else/any other agency to contact?
    Non-point source coordinator for rivers and streams – Melissa Evers (207) 287-2838

Greg Johnson
Senior Hydrologist
Minnesota Pollution Control Agency
Interviewed March 31, 2005, (651) 296-6938

1. Describe how the program works / what are the key components of the program?
   They are still in the process of developing their program- they only have 3 or 4 approved TMDLs. They built their TMDL process on an existing watershed program which was focused on non-point sources. They have a monitoring group that is responsible for developing the 303d list. The TMDL process consists of developing load and wasteload allocations, identifying the reduction needed, and developing an implementation plan within one year of notification that a reduction is needed. Although it is not required, MPCA recommends that the plan is developed at the same time as the TMDL. The development of implementation plans isn't a well-defined process yet. They generally rely on model results to make suggestions to stakeholders, then allow stakeholder groups to negotiate among themselves to develop the plan.

2. Who are your primary stakeholders?
   This varies, but priority is given to local interests – typically local units of government, especially on lakes and streams. There are also a number of lakeshore associations, made up of private property owners on lakes, and farmers. The state makes an effort to get people involved from the beginning, with stakeholder meetings and TACs for bigger TMDL projects. Some counties are fairly pro-active, and applied for funding early on TMDL projects.

3. How is the program managed? One agency, several agencies, oversight group?
   The MPCA currently manages the program entirely. However, this may change in the future. A broad stakeholder group that was instrumental in putting a water quality funding bill in front of the Legislature may contribute to the formation of a coordinating council. Implementation funding will shift from MPCA to other state agencies, though MPCA would still develop TMDL values. The MPCA doesn't have the staff necessary to do all of the work, so some would be performed by local agencies, and some might be performed by consultants.

   They apply Section 122.4 of the Clean Water Act, which states that there shall be no new or expanded discharge to a stream before the TMDL is completed. This has led to the perception that growth would be limited until TMDLs are done, which has caused the business community to get behind the TMDL effort in an effort to move it towards completion.

4. How is the program funded?
   They adapted an existing State program that provided grant funding for local diagnostic studies, including an implementation action plan. Once the implementation action plan is done, projects can apply for implementation funding from state revenues and 319 funds. They definitely do not have enough 319 funds to do TMDLs. Proposed legislation will create funding through fees on individual households of $36/year, and a sliding scale for

businesses. This is estimated to result in about $80 million/year, with a portion available for TMDL studies and the bulk available for implementation of projects.

5. How is pollutant loading determined?
   They use a range of approaches, varying from a simple spreadsheet application to an HSPF model of the Lower Minnesota River. John Butcher of TetraTech performed the HSPF analysis, which spanned 12 to 14 years (a part of the time of which the project was held up for other reasons). The model was very detailed and well-calibrated, and the results helped the general public understand a watershed approach to water quality planning.

   They may consider using SWMM or something similar in the future in more urbanized areas.

6. How are BMP efficiencies determined? Individual and treatment trains.
   They have not done this for the TMDL program. Their stormwater division is currently re-writing their urban BMP manual.

   They instead use surrogates for load reduction, with monitoring and adaptive management processes. For example, they determined that they needed a 65% reduction in fecal coliform loading in one project area. They decided that they had achieved this when 65% of the septic systems were fixed/removed and 65% of the feedlot sources were treated.

   They would like to have monitoring data for specific BMPs, and would like to design an effectiveness monitoring effort on a watershed scale. They participate in a 319 national monitoring program, which has 24 projects across the country using similar monitoring efforts to detect water quality change.

7. How do you handle retrofits of existing older projects? Private property BMPs?
   They haven't faced this within the TMDL program yet, although they have dealt with it in previous watershed projects. They believe that eventually municipal SWPPPs will tie into TMDLs.

8. What aspects of your program work well and don't work well?
   They are still developing their program, but one issue they have struggled with is not having a defined process in place; they are instead developing the program as they go. This does provide them flexibility, but often makes the process difficult.

   They also have difficulty at times with identifying the necessary level of technical rigor for a given project- sometimes less detail is needed, and sometimes more detail is needed.

9. Is there a feedback loop, whereby the program can be improved?
   They use adaptive management on individual projects, but no formal feedback loop exists at the program level. They instead modify the program continually as needs arise.

10. Do you work with pollutant trading/offsets/informal banking?
    Yes. This has mostly occurred in the Minnesota River Basin, with some point/non-point trading. They are also working on a watershed permit for wastewater facilities - the facilities within a particular watershed will work out who does the reduction.

11. Can you recommend anyone else/any other agency to contact?
    Jim Klang within MPCA – HSPF experience, pollutant trading (651) 296-8402
    Steve Heiskary within MPCA – limnology of Lake Peppin (651) 296-7217
    Ohio TMDL program – they have a different approach

Ron Entringer
Chief, Source Protection Section
New York Department of Environmental Conservation
Interviewed April 6, 2005, (518) 402-8176

1. Describe how the program works / what are the key components of the program?
   They have focused on point sources and large water bodies, such as the New York City Reservoirs, Onondaga Lake, Lake Champlain and Long Island Sound. Non-point source pollution from stormwater is being handled by MS4 communities.

2. Who are your primary stakeholders?
   Depends on the project. For Lake Champlain, there are multiple states, two EPA regions and the lake commission. For the New York City watershed, it is local landowners as well as the City. The major difference here, however, is that local landowners do not get a direct benefit for making improvements, so there has historically been an adversarial relationship between the landowners and New York City.

3. How is the program managed? One agency, several agencies, oversight group?
   Depends on the project. Large projects have some federal oversight or a structured watershed oversight group, and possibly multiple states if the project area straddles a border.

4. How is the program funded?
   It varies. New York City generally pays for work done in their watershed. The state tries to find a balance in assigning costs between the polluters and those who benefit from improvements. They use both state and federal funds, through regional federal offices.

5. How is pollutant loading determined?
   1st: Use good monitoring data to characterize pollutants. They use multiple samples during a single storm event because they realize that a single sample will not adequately characterize loading.
   2nd: They have done one small-scale model using GWLF, now Arc View compatible. It has a BMP predictor in it that helps assess load reductions.
   3rd: If nothing else is available, they use export coefficients from Reckhow.

   They don't have much faith in models in general, although they are interested in how well WEPP might work. GWLF does not have a good function for the build-up of phosphorus.

6. How are BMP efficiencies determined? Individual and treatment trains.
   They use the standard efficiencies in GWLF. In general, they struggle with BMP efficiencies because of the variability associated with them. They often use BMP information from the Center for Watershed Protection.

7. How do you handle retrofits of existing older projects? Private property BMPs?

They haven't documented how well retrofits work. New York City uses Schueler's simple method.

8. <u>What aspects of your program work well and don't work well?</u>
   They feel that their point source program works well, and their approach to agricultural runoff management works well. They are not so sure about their stormwater management programs.

9. <u>Is there a feedback loop, whereby the program can be improved?</u>
   Phased TMDLs with adaptive management.

10. <u>Do you work with pollutant trading/offsets/informal banking?</u>
    Not much – Connecticut has done some point source trading. They may in the future.

11. <u>Can you recommend anyone else/any other agency to contact?</u>
    Reggie Parrish, with the EPA's urban stormwater working group.

Trinka Mount
TMDL Coordinator
Ohio EPA
Interviewed April 5, 2005, (614) 644-2140

1. Describe how the program works / what are the key components of the program?
   They already had the individual components of the program, including monitoring, modeling and permitting, so the TMDL was defined as an integrating program that pulled from the existing programs.

   They follow a 12-step process: the first three steps involve monitoring, the middle steps (up through step 8) are the traditional TMDL process, followed by the implementation steps and finally a validation step that confirms whether the TMDL is working or not.

2. Who are your primary stakeholders?
   Farm bureau, developers, stormwater permit holders, environmental groups. They have had some trouble engaging their stakeholders early in the process if they don't think they will be affected. Municipalities will likely get involved as part of Phase II. They have also partnered with the Corps of Engineers, USFS and local universities.

3. How is the program managed? One agency, several agencies, oversight group?
   Ohio EPA manages the program.

4. How is the program funded?
   Roughly half from state general revenues, remainder from federal grants.

5. How is pollutant loading determined?
   They have used a range of model for nutrient TMDLS: GWLF, a daily timestep simulation model, that does monthly calculations for sediment and nutrient load and uses SCS methodology for hydrologic calculations; and SWAT.

6. How are BMP efficiencies determined? Individual and treatment trains.
   They have only done this on one project, although they would like to move in this direction. They have found that there is very limited data, so their work is typically qualitative.

7. How do you handle retrofits of existing older projects? Private property BMPs?
   Not applicable.

8. What aspects of your program work well and don't work well?
   Positive: they have a defined process that the public understands.
   Negative: they have found it difficult to deliver on time, and it has been difficult to engage people early enough in the process.

9. Is there a feedback loop, whereby the program can be improved?

The validation step in the TMDL process should, in theory, determine whether a project needs additional work or not.

At a program level, they are continuously, though informally, improving their program.

10. Do you work with pollutant trading/offsets/informal banking?
    They are just starting to do this in western Ohio. They encourage this but do not get directly involved. They are currently working on a policy statement regarding this.

11. Can you recommend anyone else/any other agency to contact?
    States of Washington, North Carolina and Vermont

Kathy Stecker
Section Manager of Watersheds and Planning
South Carolina Department of Health and Environmental Control
Interviewed April 5, 2005, (803) 898-4011

1. Describe how the program works / what are the key components of the program?
   They start with their state-wide 303d list to identify impaired waters. They develop TMDLs both in-house and through a group of contractors. They are currently under a court order, so the EPA is finalizing their TMDLs. They are also working on state regulations that describe the public participation and appeals process.

2. Who are your primary stakeholders?
   For determining TMDLS: point source operators, agricultural community, private property owners, municipalities, and counties. For implementation of TMDLs: conservation districts, university extensions.

3. How is the program managed? One agency, several agencies, oversight group?
   Their agency, SCDHEC.

4. How is the program funded?
   No state funding- all federal grant funds, for both development and implementation.

5. How is pollutant loading determined?
   Their primary pollutant of concern is fecal coliform, and they use the simplest methods available to develop these TMDLS (no modeling).

   They have use the WARMF model to develop a phosphorus TMDL for the Catawba River. WARMF is a continuous-simulation model that is HSPF-based. Although Ms. Stecker did not have detailed information available about this model, a quick search on the web showed that pollutant loading inputs have been determined through water quality monitoring on other projects.

6. How are BMP efficiencies determined? Individual and treatment trains.
   These are not considered during the TMDL development.
   They determine an overall non-point source allocation and reduction, but do not specify activities required to meet these targets. The specific reductions are deferred to the local level- the local governments do not generally determine actual load reductions either, using monitoring instead to determine whether their BMPs are working.

7. How do you handle retrofits of existing older projects? Private property BMPs?
   Not applicable, although they acknowledge this will be a challenge in urbanized areas.

8. What aspects of your program work well and don't work well?
   Even though the 303d list has been around a long time and they have tried to make others aware of it, there has still been a fair amount of resistance to change. They would have

therefore done more aggressive public outreach sooner to make the process smoother later on. They have a good working relationship with the EPA, good communication.

9. Is there a feedback loop, whereby the program can be improved?
   There are two primary methods: monitoring and public feedback.

   They have a statewide monitoring program that has two types of monitoring: fixed locations and probabilistic monitoring. The fixed locations are typically at the outlets of subwatersheds, while the probabilistic monitoring moves around to get an overall assessment of water quality. They monitor 1000-1500 sites around the state using grab samples for every pollutant of concern.

10. Do you work with pollutant trading/offsets/informal banking?
    No – they don't expect to be dealing with this any time soon.

    They have done watershed permitting where they allowed loads to be shared between more than one source if close spatially and similar in nature.

11. Can you recommend anyone else/any other agency to contact?
    Chesapeake Bay, Neuse River in North Carolina

Ward Ling
Project Manager
Texas Natural Resource Conservation Commission
Interviewed April 4, 2005, (512) 239-6238

1. Describe how the program works / what are the key components of the program?
   Impaired waters are identified from existing 303b lists and their Surface Water Quality Monitoring Program (SWQM). SWQM provides coordinated water quality monitoring among numerous agencies. Once problems are identified, they lump them into projects, either by geographical area or by nature of the problem. They often do more targeted monitoring once they identify a potential project. They review historical data and determine point sources and non-point sources. They are not required to develop implementation plans, but they do sometimes take a project through a Watershed Action Plan.

2. Who are your primary stakeholders?
   They have a 22-stakeholder cap, although anybody can attend meetings. The group of stakeholders depends on the watershed: municipalities, ag industries, lumber, environmental groups. There is a review team that reviews the stakeholder list to make sure that it is balanced.

3. How is the program managed? One agency, several agencies, oversight group?
   The TNRCC and the Texas State Soil and Water Conservation Board, which focuses on agriculture and silvaculture.

4. How is the program funded?
   Virtually all federal grant funding - very little state funding.

5. How is pollutant loading determined?
   They follow EPA guidance to do calculations, using an HSPF-based model. They may do something simpler in certain watersheds, as they have found that the amount of time and money spent on modeling may have been overkill in many cases.

6. How are BMP efficiencies determined? Individual and treatment trains.
   They don’t use these. The only BMPs they consider are agricultural BMPs.

7. How do you handle retrofits of existing older projects? Private property BMPs?
   Not applicable.

8. What aspects of your program work well and don’t work well?
   They are getting better at recognizing poor data sets, so they can better assess a TMDL the first time.

9. Is there a feedback loop, whereby the program can be improved?

They use data collection to monitor actual water quality improvement, and the public provides stakeholder feedback.

10. Do you work with pollutant trading/offsets/informal banking?
No.

11. Can you recommend anyone else/any other agency to contact?
Texas State soil board.

Jim Baumann
Special Assistant to Director for Bureau of Watershed Management
Wisconsin Department of Natural Resources
Interviewed April 4, 2005, (608) 266-9277

1. Describe how the program works / what are the key components of the program?
   They divided their impaired waters into 5 or 6 subcategories, including: non-point source dominated, point source dominated, a blend of nps/ps dominated, contaminated sediment and atmospheric deposition. They have a different TMDL approach to each category. E.g. they have not developed contaminated sediment or atmospheric deposition TMDLs because they don't know how to do this, and the EPA has not given them any guidance. With the blended and nps-dominated categories, the process is driven by nutrients. Urban stormwater: TMDLs would be developed and loads allocated between point source and non-point source, and would agree with other stormwater permits.

   In the future, they expect to implement performance standards/prohibitions so that loads and reductions will actually be calculated. Performance standards would specify that new development would control 80% of TSS and flow, as well as increase infiltration. In rural areas, this is only enforceable if financial assistance is available. Performance standards are in State Code – Rule NR151. Urban stormwater TMDLs are on a 5-year schedule for development and implementation; rural TMDLS will likely take 20-30 years because of lack of money and staff to perform these.

2. Who are your primary stakeholders?
   nps-dominated: farm owners/operators and cities
   Also cities for stormwater/wastewater

3. How is the program managed? One agency, several agencies, oversight group?
   DNR manages the program. They want to put as much as possible into administrative codes for the purposes of consistency, though some flexibility may be lost.

4. How is the program funded?
   TMDL development: individual EPA grants (319, 104B3), very little state money
   Implementation: 75% state funded

5. How is pollutant loading determined?
   See manuals on website – looked, did not see anything applicable.

6. How are BMP efficiencies determined? Individual and treatment trains.
   See manuals on website – looked, did not see anything applicable.

7. How do you handle retrofits of existing older projects? Private property BMPs?
   Urban stormwater grant program - $2 or 3 million available annually to retrofit properties – see their website

8. What aspects of your program work well and don't work well?

The stormwater permit program has been fairly good for changing mindsets and managing stormwater; it has made some fundamental changes.

9. Is there a feedback loop, whereby the program can be improved?
   They track the implementation of all projects, and monitor some projects. Monitoring is used to demonstrate success or identify where improvements are necessary. They have found several sites that have improved enough that they could be delisted.

   They essentially use a form of adaptive management, although they discouraged by the EPA from using this term.

10. Do you work with pollutant trading/offsets/informal banking?
    They have done a little bit with offsets and pollutant trading; one pollutant trade so far. These haven't proven viable economically, but they expect they will become a necessary component of TMDLs in the future as growth continues.

11. Can you recommend anyone else/any other agency to contact?
    North Carolina – Pamlico Sound TMDLs

Methodology to Estimate Pollutant Load Reductions

Appendix E – Literature Search Database

Final Report

Prepared for:
US Army Corps of Engineers
1325 J Street
Sacramento, CA 95814

Lahontan Regional Water Quality Control Board
2501 Lake Tahoe Boulevard
South Lake Tahoe, CA 96150

Prepared by:
Northwest Hydraulic Consultants, Inc.
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Contract DACW05-02-D-0001-0007-01
April 21, 2006

Literature Search Database

Reference ID 2

Braskerud, B.C. (2002). "Factors Affecting Phosphorus Retention in Small Constructed Wetlands Treating Agricultural Non-point Source Pollution." Ecological Engineering, 19 (1): 41-61.

Keywords: aggregates, arable fields, cold climate, dissolved phosphorus, prediction model, sedimentation, selective erosion, stormwater, surface-flow wetlands, total phosphorus

☐ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

Four surface flow constructed wetlands (CWs) have been intensively investigated for phosphorus retention, from 3 to 7 years in the cold temperate climate of Norway. The aim of this study was to identify factors that affect phosphorus retention from non-point sources. The wetlands were located in first order streams, with surface areas of 0.06-0.4% of the watershed (CW-area 350-900 m(2)). Volume proportional composite samples were taken from inlet and outlet, and sedimentation plates were used in selected areas. The average retention of total phosphorus for the individual CWs was 21-44% of input, despite the high hydraulic load (mean load was 0.7-1.8 in per day). This equals a retention of 26-71 g phosphorus m(-2) surface area per year. A first-order model was fitted to the data giving an average removal constant, k, of 214 in per year. However, the constant increased with increasing hydraulic load due to the simultaneous increase in particle settling velocity. Hence, retention increased in spite of increasing hydraulic loads. Moreover, linear multiple regression models showed that retention was influenced by several external variables, e.g. input of phosphorus, season, phosphorus content on suspended solids and phosphorus settling velocity. The results suggest that the first-order model is less suitable to estimate phosphorus retention in similar gravity fed wetlands. The best of the proposed statistical prediction models, reproduced observed data from two independent test-CWs with a deviation of 0.1%. The investigation shows that small wetlands are a useful supplement to best management practice on arable fields. However, the present study focuses on the necessity to investigate how pollutants enter wetlands. Such knowledge can then be used to suggest improvements of wetland layout.

Reference ID 3

Wittgren, H.B. and Maehlum, T. (1997). "Wastewater Treatment Wetlands in Cold Climates." Water Science and Technology, 35 (5): 45-53.

Keywords: cold climate, design, geographical distribution, hydrology, operation, plant uptake, purification processes, nutrient removal, treatment wetlands, treatment performance, wastewater

☐ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The best prospects for successful wetland treatment should be in the warmer regions of the world, but studies in North America and Scandinavia show that wetland treatment may be feasible also in cooler regions. A review shows that the number of wetlands of different types (free water surface, FWS; horizontal and vertical subsurface flow, SSF), treating different kinds of wastewater, is steadily increasing in most parts of the cold temperate regions of the world. The major wetland engineering concerns in cold climates, which are discussed in this paper, are related to: (1) ice formation, and its implications for hydraulic performance; (2) hydrology and hydraulic issues besides ice formation; and (3) the thermal consequences for biologically or microbiologically mediated treatment processes. Energy- and water-balance calculations, as well as thermal modeling, are useful tools for successful design and operation of treatment wetlands, but the shortage of data makes it necessary to adopt a conservative approach. The treatment processes often appear less temperature sensitive in full-scale wetlands as compared to laboratory incubations. Several possible explanations are discussed in the paper: (1) sedimentation playing a significant role, (2) overdimensioning in relation to some constituents, (3) seasonal adsorption (cation exchange) of ammonium, and (4) temperature adaptation of the microbial community. Experience shows that cold climate wetlands can meet effluent criteria for the most important treatment parameters. To gain wide acceptance, however, we need to become more specific about design and construction, and also about operation, maintenance and cost-effectiveness. These goals require detailed knowledge about processes in full-scale wetlands, including long-term changes and response to maintenance.

Reference ID 6

Tanner C.C., Sukias J.S. and Upsdell M.P. (1998). "Relationships Between Loading Rates and Pollutant Removal During Maturation of Gravel-Bed Constructed Wetlands." Journal of Environmental Quality, 27 (2): 448-458.

Keywords: dairy farm wastewaters, waste-water treatment, phosphorus removal, nitrogen, hydrosphere, phosphine, solids

☐ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Relationships between pollutant mass loading and removal are reported for a series of five pilot-scale constructed wetlands in their 4th and 5th years of operation. The wetlands received different hydraulic loadings ranging between similar to 15 and 70 mm d(-1) (9.5-2 d theoretical retention, respectively), Effluent concentrations of 5-d carbonaceous biochemical oxygen demand (CBOD), total nitrogen (TN), ammonium N (NH4N), and fecal coliforms (FC) broadly followed seasonal patterns in influent wastewater strength, Mean annual mass removals of 58 to 78% suspended solids (SS), 73 to 91% CBOD, 48 to 65% TN, 34 to 60% NH4-N, 15 to 38% total phosphorus (TP), and 93 to 99.6% of FC were recorded, with removal efficiencies inversely related to loadings, Mass removal rates were monotonically related to loading rates, and could be modeled using a simple plug-flow, first-order approach accounting for removal down to nonzero background concentrations, Comparisons with treatment performance recorded for the wetlands soon after commissioning showed relatively constant relationships between mass loading and removal of CBOD, TN, and FC, In contract, SS and TP removal declined significantly over the same period, Reduced SS removal efficiency appeared to result from clogging of the gravel substratum by refractory organic solids, and reduced TP removal from saturation of substratum sorption capacity and filling of plant storage pools. To improve N removal predictions for wetlands treating ammonium-rich wastewaters, the use of a combined carbonaceous and nitrogenous BOD term is proposed, which addresses the oxygen dependence of microbial nitrification, the principal rate-controlling process.

Reference ID 7

Kadlec, R.H. (1999). "Chemical, Physical and Biological Cycles in Treatment Wetlands." Water Science and Technology, 40 (3): 37-44

Keywords: biogeochemistry, constructed wetlands, cycles, pollutant removal, temperature, vegetation, water flows

☐ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Treatment wetlands are solar powered ecosystems. Solar radiation varies diurnally, as well as on an annual basis. Wetland processes are therefore driven to respond on these same two cyclic periods. The first and most obvious effect is on the temperature of the water and soils in the wetland. Intense summer radiation results in warmer conditions and higher evapotranspiration, Winter radiation is smaller, and results in cooler temperatures and less evapotranspiration. Other meteorological variables, such as air temperature, humidity and precipitation, also have annual cycles, but with considerable stochastic variability. The water and soil temperature variations cause changes in microbial activity, which in turn creates changes in microbially-mediated water quality improvement. The cyclic changes in rain and evapotranspiration may create significant effects on the water budget for the wetland, and thus influence treatment efficiency. In addition, there are seasonal cycles in the vegetation and litter in the system, which occur in response to solar inputs and meteorological factors. This causes seasonal changes in nutrient and chemical uptake and release. This combination of cyclic influences is reflected in the treatment performance of the constructed wetland. It is shown that wetland water temperature alone is not a sufficient descriptor of wetland biogeochemical cycles. Mass balances demonstrate cyclic interactions in treatment wetlands. The effects of vegetative cycles are quantified for an example system.

Reference ID 8

Dogrul, E.C., Kavas, M., Levent, Aksoy, and Hafzullah. (2001). "Effects of Urbanization on the Suspended Sediments from an Intervening Zone of Lake Tahoe." Hydrologic Research Laboaratory Report Series, Report No. 2, University of California,

Keywords: nutrients, sediments, source, intervening zone, SWMM, GIS, snowmelt, rainfall, runoff quantity and quality.

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Identification of the sources of sediment and nutrients that eventually affect the clarity of Lake Tahoe has recently been an important issue. Until now, most studies have concentrated on the identification of such sources in watersheds of Tahoe basin and the zones that intervene the watersheds have been ignored. The goal of this study is to analyze the effect of urbanization on sediment and nutrient loads in an intervening zone located between Carnelian Bay and Kings Beach. 49.9% of this intervening zone is urbanized and the rest of it is rural. The U. S. Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) is used to simulate the quantity and quality of urban storm water runoff. The UC Davis Hydrologic Research Laboratory rural watershed hydrology and erosion model is coupled with SWMM in order to model the runoff in the rural part of the intervening zone. The coupled model can simulate runoff quantity and quality due to snowmelt as well as rainfall events. For this study, the storm drain network was mapped and the major outlets were identified. Then the areas draining into these outlets were obtained by the analysis of digital elevation maps (DEM) using GIS (Figure 1). GIS was also used in order to obtain other parameter values regarding soil characteristics, topography, road and storm drain network. At this point in time, the model is being calibrated for several snowmelt and rainfall events that were observed in the year 1999. After the calibration is completed, the percentage of urbanization in the intervening zone will be modified and the runoff quantity and quality will be simulated. It is expected that the analysis of the results obtained for different percentages of urbanization will lead to the understanding of the effect of urbanization on the sediment and nutrient loads transported to Lake Tahoe.

Reference ID 9

Reuter, J.E., Heyvaert, A.C., Luck,M., Hackley, S.H. (2001). "Land Use Based Stormwater Runoff Monitoring Evaluation of BMP Effectiveness in the Tahoe Basin." Tahoe Research Group, UC Davis, December 2000

Keywords: Land use, nutrients, sediments, source, BMPs

☐ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

This study provides nutrient and sediment concentration in the stormwater runoff monitored at 17 site/studies in the lake Tahoe Basin. Useful information on landuse type relationship with runoff quality aggregated from the 17 sites is presented. Effectiveness of 19 individual projects included in this report provides %removal efficiencies. Performance of BMPs grouped by classification were then compared with the Nationa Database. Overall, removal efficiencies seen in National Database were better than values measured for BMPs in Lake Tahoe.

Reference ID 10

Reuter, J.E., Heyvaert, A.C., Hackley, S.H. (2000). "Preliminary Analysis of Sediments and Phosphorus in the Surface Runoff from Selected Intervening Zones in the Tahoe Basin: 1998-1999 Monitoring." Tahoe Research Group, UC Davis, December

Keywords: Phosphorus, runoff concentrations, land use, hydrological events, season

☐ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☒ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Sediment and phosphorus runoff were collected from selected intervening zones in Lake Tahoe Basin. Water quality data including TSS, Dissolved Phosphorus, Total Phosphorus and Particulate Phosphorus was analyzed. Data was analyzed from seasonal variations, natural versus urban loading, influence of hydrological events (rain Vs snowmelt Vs rain on snow). Seasonality was observed in the concentration of particulate phosphorus as its concentration reached zero during spring snowmelt period of May-June. However concentration of DP remained uniform throughout the year with no significant change.

TSS concentration was found to be at least 100-fold greater in the urbanized zone than the undisturbed zone. Hydrological events had some effect on the transport of PP but no effect on the TSS.

Reference ID 11

Caltrans (2002). "Tahoe Highway Runoff Characterization and Sand Trap Effectiveness Studies 2001-2002 Monitoring Session." CTSW-RT-02-044, California Department of Tansportation, Sacramento, CA

Keywords: Lake Tahoe Basin, runoff, water quality, particle and sediment characterization, sand trap removal effectiveness

☐ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☒ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

This report presents results and data evaluations of the Tahoe Basin Stormwater Runoff and Sand Trap Monitoring Porgram conduted by the California Department of Tansportation (Caltrans). This report presents data from the second period of Monitoring in the Lake Tahoe Basin performed form August 2001 to April 2002. Results include runoff water quality and particle and sediment chracterization and sand trap treatment and removal effectiveness. Runoff water quality evaluation results indicated the levels of TDS and metals were significantly higher and conversely the levels of nutrient concentrations lower after the start of snow management activities. Land use type (urban Vs rural) and elevation (low Vs high) have indirect impact on runoff water quality. Low elevation and urban sites were observed to have higher constituent concentrations than high elevation and rural sites.

Sand Trap Effectiveness: Data analysis indicated that sand traps reduced effluent concentrations for 19 out of 34 paramenters evaluated. However, sand traps were observed to be the source of contamination for 9 out of 34 water quality parameters. For nutrients the sand traps provided the most treatment for orthophosphate, dissolved phosphorus and TKN. Overall, runoff constituent concentrations exceeded the stormwater discharge limits established for Lake Tahoe Basin.

Reference ID 15

Semadeni-Davies A (1998). "Modeling Snowmelt Induced Waste Water Inflows." Nordic Hydrology, 29 (4-5): 285-302

Keywords: Glacial till slope, runoff, snowmelt,

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Impacts of urbanisation on hydrological processes are different for snowmelt and rainfall events. Furthermore, snowmelt and runoff generation differ between rural and urban areas. Within an urban area, melt intensities are increased at some sites; hence, the volume of water early in thaw can be greater than in rural areas. However, shading can reduce melt in other areas so that the melt period is extended. Many surfaces are at least seasonally impervious and generate overland flow - there is an apparent increase in the area contributing to quickflow as normally permeable surfaces become saturated or frozen or both. Water infiltrating permeable soil causes saturation and groundwater recharge so that water can seep into sewers. Regardless of whether water enters via inlets or sewer infiltration, drainage networks ensure swift delivery of melt water to outlets.

Snowmelt induced runoff reaching the Uddebo Waste Water Treatment Plant in Lulea, Sweden, is investigated and a model of urban snowmelt and meltwater routing is proposed. The role of surface type (permeable and impervious) and snow cover characteristics (snow-free, undisturbed, compacted and piled) upon model output is studied. Results are encouraging and provide a good platform for further research.

Reference ID 16

Brezonik P.L. and Stadelmann T.H. (2002). "Analysis and Predictive Models of Stormwater Runoff Volumes, Loads, and Pollutant Concentrations from Watersheds in the Twin Cities Metropolitan area, Minnesota, USA." Water Research, 36 (7): 1743-1757.

Keywords: urban stormwater, urban runoff, diffuse-source pollution, nutrients, nitrogen, phosphorus, event-mean concentrations, event loads

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Urban nonpoint source pollution is a significant contributor to water quality degradation. Watershed planners need to be able to estimate nonpoint source loads to takes and streams if they are to plan effective management strategies. To meet this need for the twin cities metropolitan area, a large database of urban and suburban runoff data was compiled. Stormwater runoff loads and concentrations and watershed characteristics were examined. The best regression equation to predict runoff volume for rain events was based on rainfall amount, drainage area, and percent impervious area (R-2 = 0.78). Median event-mean concentrations (EMCs) tended to be higher in snowmelt runoff than in rainfall runoff, and significant seasonal differences were found in yields (kg/ha) and EMCs for most constituents, Simple correlations between explanatory variables and stormwater loads and EMCs were weak. Rainfall amount and intensity and drainage area were the most important variables in multiple linear regression models to predict event loads, but uncertainty was high in models developed with the pooled data set. The most accurate models for EMCs generally were found when sites were grouped according to common land use and size.

Reference ID 17

Bengtsson L. and Singh V.P. (2000). "Model Sophistication in Relation to Scales in Snowmelt Runoff Modeling." Noridic Hydrology, 31 (4-5): 267-286.

Keywords: frozen soils, meltwater, groundwater, movement, infiltration, radiation, pathways, water, cover

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Snowmelt induced runoff from river basins is usually successfully simulated using a simple degree-day approach and conceptual rainfall-runoff models. Fluctuations within the day can not be described by such crude approaches. In the present paper, it is investigated which degree of sophistication is required in snow models and runoff models to resolve the basin runoff from basins of different character, and also s of different degree of sophistication are tested on basins ranging from 6,000 km(2) down to less than 1 km(2). It is found that for large basins it is sufficient to use a very simple runoff module and a degree day approach, but that the snow model has to be distributed related to land cover and topography. Also for small forested basins, where most of the stream flow is of groundwater origin, the degree-day method combined with a conceptual runoff model reproduces the snowmelt induced runoff well. Where overland flow takes place, a high resolution snow model is required for resolving the runoff fluctuations at the basin outlet.

Reference ID 19

Feng X.H., Taylor S., Renshaw C.E. and Kirchner J.W. (2002). "Isotopic Evolution of Snowmelt - 1. A Physically Based One-Dimensional Model." Water Resources Research, 38 (10)

Keywords: snowmelt, oxygen isotopes, modeling, spring runoff, hydrograph separation, runoff, water, flow, transport, meltwater, catchment, exchange, terrain, melt

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The O-18/O-16 ratio of snowmelt from a seasonal snowpack typically increases with time as the melting process progresses. This temporal evolution is caused by isotopic exchange between liquid and ice as meltwater percolates down the snow column. Consequently, hydrograph separations of spring runoff using the bulk snow composition as the new water end-member will be erroneous. Accurate determinations of the new water input should take into account the temporal variation of the snowmelt. Here we present a one-dimensional (1-D) physically based model for the isotopic evolution of snowmelt. Two parameters, the effective rate of isotopic exchange between water and ice and the ice to liquid ratio of the exchange system, are important for controlling the range and temporal pattern of the isotopic variation in snowmelt. For all plausible values of these parameters the modeled isotopic signature of snowmelt changes by 1-4parts per thousand as snowmelt progresses. These isotopic shifts will affect the results of hydrograph separations.

Reference ID 20

Taylor S., Feng X.H., Renshaw C.E. and Kirchner J.W. (2002). "Isotopic evolution of snowmelt - 2. Verification and parameterization of a one-dimensional model using laboratory experiments." Water Resources Research, 38 (10)

Keywords: snowmelt, oxygen 18 composition, laboratory experiments, isotopic exchange rate constant, hydrograph separation, snowmelt

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Three controlled cold room experiments were conducted to verify and parameterize a one-dimensional (1-D) model that simulates the isotopic composition of meltwater exiting the base of a snowpack. In the model, snow melts at the surface at a constant rate, and water percolates down the column while exchanging isotopically with ice. The effective rate of isotopic exchange and hence the isotopic composition of the melt at a given time is determined by the exchange rate constant kr, the height of the original snowpack, the percolation velocity u*, and the liquid to ice ratio in the exchange system. The experiments were designed to have different effective rates of exchange by varying the height of the snow column and the melt rate. Fitting the model to each of the experiments yielded kr values that fall in a narrow range, 0.14 to 0.17 hr(-1), confirming that kr is an intrinsic rate constant for isotopic exchange. Knowing this value is important for developing future models, in which more complicated hydrological conditions are considered.

Reference ID 26

Coats R., Liu F.J., Goldman C.R. (2002). "A Monte Carlo Test of Load Calculation Methods, Lake Tahoe Basin, California-Nevada." Journal of the American Water Resources Association, 38 (3): 719-730.

Keywords: aquatic ecosystems, statistical analysis, water quality, watershed management, Lake Tahoe, eutrophication, load calculation

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The sampling of streams and estimation of total loads of nitrogen, phosphorus, and suspended sediment play an important role in efforts to control the eutrophication of Lake Tahoe. We used a Monte Carlo procedure to test the precision and bias of four methods of calculating total constituent loads for nitrate-nitrogen, soluble reactive phosphorus, particulate phosphorus, total phosphorus, and suspended sediment in one major tributary of the take. The methods tested were two forms of the Beale's Ratio Estimator, the Period Weighted Sample, and the Rating Curve. Intensive sampling in 1985 (a dry year) and 1986 (a wet year) provided a basis for estimating loads by the "worked record" ensity that characterizes the present monitoring program. The results show that: (1) the Period Weighted Sample method was superior to the other methods for all constituents for 1985; and (2) for total phosphorus, particulate phosphorus, and suspended sediment, the Rating Curve gave the best results in 1986. Modification of the present sampling program and load calculation methods may be necessary to improve the precision and reduce the bias of estimates of total phosphorus loads in basin streams.

Reference ID 27

Hatch L.K., Reuter J.E., Goldman C.R. (1999). "Daily phosphorus variation in a mountain stream." Water Resources Research, 35 (12): 3783-3791.

Keywords: nutrient transport, Lake Tahoe, ecosystem, runoff, sediments, nitrogen, dynamics, export, basin, water

☐ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

Monthly diel monitoring studies for phosphorus content were conducted (1995-1996 period) for multiple stations on Incline Creek, a mountain stream in the Lake Tahoe basin (California-Nevada). Large discharge and particulate P (PP) concentration fluctuations occurred during June in the early evening as snowmelt from higher elevations arrived at the lower stream reaches. June diel dissolved organic P (DOP) reactive P (SRP) concentrations remained constant. June diel PP concentrations associated with sand-sized particles (PPsand: >63 mu m) exhibited a clockwise hysteresis, indicating possible sediment source depletion on a daily timescale. June diel PP associated with silt- and clay-sized particles (PPsc: >0.45 mu m and <63 mu m) exhibited counterclockwise hysteresis behavior, suggesting a potential groundwater contribution to PPsc. PPsc comprised the majority of PP concentration, except during high-discharge events when PPsand, concentration was dominant. Areal PP loading, specifically PPsand, appears to originate primarily from the lower eastern branch of Incline Creek during the spring snowmelt season. Possible sources include a ski resort/parking lot and a golf course. DOP and SRP areal loads were greatest from the undeveloped upper subwatershed, suggesting that natural factors such as slope are influencing loading of small-sized P fractions.

Reference ID 29

Hatch L.K., Reuter J.E., and Goldman C.R. (2001). "Stream phosphorus transport in the Lake Tahoe basin, 1989-1996." Environmental Monitoring and Assessment, 69 (1): 63-83.

Keywords: Lake Tahoe, phosphorus, streams, water quality, watershed characteristics

☐ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

Lake Tahoe is undergoing the initial stages of cultural eutrophication due to human alteration of the airshed and watershed. The lake's switch from nitrogen (N) to phosphorus (P) limitation has been attributed primarily to atmospheric N loading. This places an increased importance on controlling watershed movement of P to the lake. A stream water quality monitoring data set consisting of nine streams in the Lake Tahoe basin has been analyzed to characterize the spatiotemporal variation of P delivery to the lake. This data is from the Lake Tahoe Interagency Monitoring Program (LTIMP), which provides scientific data for planning and regulatory agencies to address environmental problems in the Lake Tahoe basin. Results indicate that P delivery (concentrations, loads) varies greatly at interannual, centrations can vary up to three orders of magnitude in a given stream and are strongly associated with suspended sediment. Particulate P is the major form of P transported by Tahoe streams and was strongly correlated with percent surficial geologic deposits, which are primarily located near streams. Tahoe streams with the highest annual P concentrations often had the lowest annual P loads, and visa versa. P loading is greatest during the spring snowmelt (75% of annual average). Potential watershed parameters influencing P delivery to Lake Tahoe have been identified as precipitation, basin area, basin steepness, and road and human development coverage. Results also suggest that human development impacts on stream P loads are most prevalent during high precipitation years. Identification and quantification of stream sediment and P sources such as streambanks and impervious surface is necessary to aid in watershed restoration efforts.

Reference ID 30

Moustafa, M.Z. (1999). "Analysis of phosphorus retention in free-water surface treatment wetlands." Hydrobiologia, 392 (1): 41-53.

Keywords: Wetlands, Everglades, nutrient removal, efficiency diagram, water residence time, phosphorus loading, retention, water loading

☐ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

Wetlands have become the focus of numerous research and restoration efforts due to their ability to assimilate phosphorus and nitrogen from urban wastewater and stormwater runoff. Long-term data collected at Boney Marsh, Florida, USA, and the USEPA wetland database were analyzed to develop a simple tool that can be used to predict and optimize phosphorus retention in wetland treatment systems. Wetland properties such as water loading rate, water depth, P-loading rate, and water retention time were examined for their influence on phosphorus retention. The relationship between wetland properties and phosphorus removal efficiency was reduced to a simple quantitative diagram provides a simple management tool that predicts expected treatment range using controllable hydrologic conditions.

Reference ID 38

Crompton, J.E., Glen, W.H., Williams, R.P. (2002). "Estimated Flood Flows in the Lake Tahoe Basin, California and Nevada." USGS Fact Sheet, FS-035-02, http://water.usgs.gov/pubs/fs/fs03502/fs03502.pdf

Keywords: Lake Tahoe, flood control, design event, peak flows, precipitation, rain-on-snow event

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

As part of the Lake Tahoe Interagency Monitoring Program, the USGS estimated flood frequencies of contributing streams to Lake Tahoe. Flood estimates were calculated for 46 sites in 21 watersheds. The USGS estimates the peak flow magnitude for a 50-yr and 100-yr recurrence interval event. In the Lake Tahoe basin, observed precipitation varies from 40-in/yr on the east side to 90-in/yr on the west side. The paper presents a table of estimated peak discharges for a 50-yr and 100-yr event as well as the largest observed flood peak. According to the table, peak flows at 31 monitoring sites were observed in January of 1997. This was the effect of an extensive rain-on-snow event.

Reference ID 49

Nissen, J. (2002). "Basin Specific Feasibility Studies- Everglades Stormwater Program Basins- Final Report." Prepared for the South Florida Water Management District, Contract C-E024, http://glacier.sfwmd.gov/org/erd/bsfboard/BSFS_ESP_Final_Report.pdf

Keywords: best management practice, advanced treatment technologies, flocculation, coagulation, alum, ferric chloride, total phosphorous, orthophosphate, organic phosphorous

☐ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

In an effort to reduce nutrient discharge into the Everglades Protection Area, the Everglades Forever Act (EFA) is anticipated to establish a total phosphorous criterion of 10-ppb. This stringent criterion would require the use of advanced treatment technologies (ATT) such as chemical treatment/ solid separation, low-intensity chemical dosing in wetlands, managed wetland treatment systems, submerged aquatic vegetation/ limerock, and periphyton-based stormwater treatment areas. The goal of the ATTs would be to treat surface waters released from Lake Okeechobee and runoff generated from the Everglades Agricultural Area (EAA). The purpose of this study was to model (bench scale) certain treatment alternatives to develop the best management strategy for six basins draining into the everglades. Of the chemical alternatives evaluated, chemical treatment/ solids separation (CTSS) proved to be one of the most effective strategies in reducing total phosphorus. Ferric chloride and alum were used as coagulants. The results revealed that orthophosphate was easier to remove than polyphosphate and organic phosphorous and that CTSS was capable of reducing total phosphorous concentrations to 10-ppb.

Reference ID 55

Reuter, J.E. (2003). "Lake Tahoe Basin Stormwater Runoff Monitoring to Assess Nutrient and Sediment Loading by Source and Land Use, Hydrologic Modeling, and Best Management Practices Effectiveness and Feasibility, 2nd Progress Report (January 1, 2003-April 31, 2003)." Prepared for the Tahoe Research Group, University of California, Davis, Agreement No.

Keywords: runoff data, event type, peak flow, volume, constituents

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☒ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

This study provides list of TMDL implemented autosampler sites and drainage characteristics, runoff event characteristics and samples collected by site and sample TRG datasheet for analyses of samples collected through first quarter. This is an ongoing study.

Reference ID 56

Heyvaert, A.C., Reuter, J.E., and Hackley, S.H. (2001). "Progress Report And Preliminary Results From Monitoring And Evaluation of Selected California Tahoe Conservancy Stormwater Treatment Projects." Prepared for the Tahoe Research Group, University of California, Davis.

Keywords: runoff data, water quality, nutrients, wetlands, efficiency

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

Provides results of stormwater runoff study conducted at five sites and monitoring data from two wetlands. Provides summary data and statistical analyses are provided provided. Event based hydrograph and loading estimates are also provided for one site. Results indicate clear seasonal patterns in the nutrient loadings. Both dissolved phosphorus and NO3 are observed to peak during spring snowmelt. Preliminary wetlands data show 80% removal rate for nutrients.

Reference ID 74

Ho, C-L. (2002). "Urban Snow Hydrology and Modeling." Report presented to the University of Calgary, Geomatics Engineering, Calgary, B.C., Thesis Number 20169. [Online] http://www.geomatics.ucalgary.ca/links/GradTheses.html

Keywords: snowmelt, snow, hydrology, Calgary, modeling

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Urban winter hydrology has garnered very little attention due to the general notion that high intensity rainfalls are the major flood-generating events in urban areas. As a result, few efforts have been made to research urban snow and its melt characteristics. This study investigated the characteristics of urban snow that differentiates it from rural snow, and the impact of incorporating these characteristics in an urban snowmelt model. A field study was conducted from fall of 2001 to spring of 2002 at the University of Calgary campus. Data collected includes snow depth and density, soil moisture, soil temperature, snow albedo, net radiation, snow evaporation, and surface temperature. Snow cover was classified into several types; snow piles, snow on road shoulders, snow on sidewalk edges, and snow in open areas. This resulted in the development of four separate functions for the changing snow albedo values. Shortwave radiation was found to be the main source of energy for urban snow, and as a consequence, the albedo of urban snow is a very important factor in urban snowmelt modelling. In addition, urban elements such as vehicle traffic and buildings can influence the energy balance of the snowpack. A study of the frozen ground conditions reveals that antecedent soil moisture conditions had very little impact on frozen ground, and thus frozen ground acts as a near impervious area. In the modelling component of this study, urban snowmelt was modeled using the energy balance method with hourly time steps and the incorporation of snow redistribution, and hence the simulation of snow piles. Three simulated tests of varying conditions revealed that peak volume, time to peak and runoff period differs for areas with snow piles versus a uniform urban snow cover. Simulation of rain-on-snow events revealed a sharp increase in runoff peak volume. Hence, under the adverse condition of intense snowmelt, frozen ground, and rainfall, flooding in urban areas can easily occur. Improved flood forecasting for urban catchments in cold regions can only be achieved with accurate modelling of urban winter runoff that involves the energy balance method, incorporating snow redistribution and urban snow cover characteristics, and using small time steps.

Reference ID 76

Hinckley, J.A., Jr. (1996). "Object-GAWSER Object-Oriented Guelph All-Weather Storm-Event Runoff Model Phase I: Training Manual Application of Object-Oriented Simulation to Hydrologic Modeling." US Army Coprs of Engineers Special Report 96-4. [Online] http://www.crrel.usace.army.mil/techpub/CRREL_Reports/reports/SR96_04.pdf

Keywords: Object-oriented, snowmelt, runoff, modelling, hydrology

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Hydrologic models are currently used to understand the economic and ecological imacts of hydrologic processes. A new hydrologic model entitled Object-GAWSER was designed using an object-oriented platform to provide new insights into watershed hydrology. Object-GAWSER is a temperature index model that simulates upland watershed hydrology. Object-GAWSER is different from other hydrologic models in that each one of its components can be easily studied to understand its sensitivity to various inputs. First, this report will show how Object-GAWSER can be used to simulate the hydrologic behavior of forested, agricultural, and suburban watersheds.

Reference ID 79

Reuter, J.E., Heyvaert, A.C., Luck, M. and Hackley, S.H. (2001). "Investigations of Stormwater Monitoring, Modeling, and Effectiveness in the Lake Tahoe Basin." Prepared for the Tahoe Research Group, University of California, Davis.

Keywords: Lake Tahoe BMPs, runoff, effluent quality

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

This document includes three separate study reports regarding the the effect of urbanization (Dogrul et al., October 2001), land use based runoff monitoring (Reuter et al., November 2001) and analysis of sediment and phosphorus in intervening zone runoff (Reuter et al., December 15, 2000). In Appendix B, a listing of about 20 BMPs implemented in Lake Tahoe Basin and a comparison of their influent and effluent water quality are given. Good source of information for Lake Tahoe urban runoff charactersitics and related BMP performance.

Reference ID 80

Hydro Science (1999). "Bioavailable Nutrient Loading into Lake Tahoe and Control Opportunities with an Empahsis on Utilizing SEZs to Treat Urban Runoff." Prepared for Tahoe Regional Planning Agency.

Keywords: Lake Tahoe, runoff, bioavailable nutrients, wetlands, SEZs, BMP performance

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

According to this study urbanization has an effect on nutrient loading as the nutrient loads/unit area is about 18 times more than the non-urbanized areas. At present there is little control of the bioavailable nutrient loading into the lake as basinwide erosion control efforts has litlle effect on removing dissolved nutrients and fine sediments. Average removal efficiencies of BMPs and SEZ restoration projects are -10, 10, 16 percent respectively for nitrate ammonium and orthophosphate.

According to this study, removal rates of 50-90% observed at two project sites in Lake Tahoe where due to shallow, dispersed flow through the meadows seems to be the feature responsible for the effectiveness. It also recommends limiting maximum average depth of water quality basins to 12-18 inches, preferably 12 inches, a length to width ratio of at least 3:1 and a deep water forebay for sedimentation and for increasing the nutrient removal.

Some of the recommendations from this study include:
1. All water quality policies should focus on control of bioavailable nutrients instead of sediment.
2. BMPs should focus on removal of dissolved nutrients and fine particulates.
3. Control efforts should be redirected from erosion control toward control of urban runoff and atmospheric desposition.

Reference ID 81

Reuter, J.E. and Miller, W.W. (2000). "Aquatic Resources, Water Quality, and Limnology of Lake Tahoe and its Upland Watershed." in The Lake Tahoe Watershed Assessment, Murphy and Knopp eds.,

Keywords: Lake Tahoe, nutrients, sediments, sources, loads, and water quality

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☒ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

This watershed assessment of the Lake Tahoe basin in northern California and Nevada is the first attempt to collate, synthesize, and interpret available scientific information with a comprehensive view toward management and policy outcomes. The seven-chapter report presents new and existing information in subject areas pertinent to policy development and land and resource management in the basin, including environmental history, air quality, watershed dynamics and water quality, biological integrity, and socioeconomic conditions. Key findings report the extent of recent climatic changes, historic accounts of past environmental disturbances, state of our understanding of why the Lake's clarity is declining, significant role that air quality plays in the decline, and an initial nutrient budget for nitrogen and phosphorous that are believed to fuel algae growth. In addition, important new work related to old-growth forests, the risk of wildfire and the conservation of biological diversity in the basin have helped to broaden our perspective of the interrelated nature of the environmental challenge facing the basin. A detailed analysis of institutional arrangements and capacities in the Lake Tahoe basin is presented in the context of environmental decision-making.

Provides good documentation of current sources and sinks of nutrients to Lake Tahoe. Calculation of nutrient loading from runoff from a limited database indicates that urban runoff contributed more nutrients compared to the non-urban sources. According to this study, using the field concentrations measured in the sumnmer of 1998 the average TSS:TP ratio was estimated at 0.0007. Concentration of total-P per unit of wet sediment in single sample ranged from 0.0013 to 0.00003 g TP per g sediment. The mean values of TP per g of wet weight sediment at the sampling sites ranged from 0.00041 to 0.00098. This chapter provides another useful information regarding variability of nutrient content in sediments from same as well as different sources. On the order of one to six percent of TP was determined to be biologically available P as determined by chemical testing. A summary information of nutrient input is provided. While major source for nitrogen loading is atmospheric deposition, surface runoff (direct runoff 34% and stream loading 29%) is the major source for total P loads. This study clearly suggests the importance of direct runoff. Another study reported in this chapter relates movement of water, nutrients and sediments.

Reference ID 89

Bernier, P. Y. (1985). "Variable Source Areas and Storm-Flow Generation: An Update of the Concept and a Simulation Effort." Journal of Hydrology, 79(3-4)

Keywords: variable source areas, hydrologic model, subsurface flow

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

VSAS2 is a deterministic storm-flow simulator for small forested basins based on the variable source area concept. Basins are divided into a number of sub-basins or segments. In each segment, subsurface flow is reduced to a two-dimensional flow problem while the third dimension is represented by segment convergence or divergence to the stream. The irregular, time-varying grid attempts sensitive representation of the variable channel system, while keeping grid size within computational feasibility. Mathematical stability of the explicit solution is secured by proper combinations of time and space increments. The performance of VSAS2 on a 24 ha Georgia Piedmont basin is poor for large winter storms and small summer storms. Discrepancies are traced to inadequate representation of both micro-relief and soil-water properties.

Reference ID 90

Noguchi, M.; Hiwatashi, T.; Mizuno, Y.; Minematsu, M. (2002). "Pollutant runoff from non-point sources and its estimation by runoff models." Water Sci. Technol., 46(11-12): 407-412.

Keywords: tank model, kinematic wave model, GIS model, pollutant loads, non-point source

☒ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

In order to attain a sound and sustainable water environment, it is important to carry out the environmental management of the watershed. For this purpose, knowledge on the pollutant runoff mechanism from non-point sources becomes very important especially under rainy conditions. At Isahaya, Nagasaki, Japan, a big project of construction of sea-dyke and reclamation is now going on, so reducing the pollutant runoff, especially from non-point sources, becomes more important. Some runoff models of rainwater are developed to predict the rate of pollutant loads from the non-point sources, and their results are compared with each other to investigate the accuracy of prediction. In this paper, runoff analysis of both rainwater and pollutants has been carried out using three models: the tank model, the kinematic wave (K-W) model, and a model using the digital elevation model (DEM). For precise estimation, it becomes necessary to identify the parameters included in these models. Here, total nitrogen has been considered as pollutants, and detachment rates are evaluated, correlated with a class of land use, soil type, and moisture content. Finally, it has been shown that pollutant runoff from non-point sources can be predicted fairly well, identifying the model parameter appropriately.

Reference ID 91

Vaze, J. and Chiew, F.H.S. (2003). "Comparative evaluation of urban storm water quality models." Water Resour. Res., 39(10)

Keywords: regression model, pollutant loads, water quality

☒ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The estimation of urban storm water pollutant loads is required for the development of mitigation and management strategies to minimize impacts to receiving environments. Event pollutant loads are typically estimated using either regression equations or "process-based" water quality models. The relative merit of using regression models compared to process-based models is not clear. A modeling study is carried out here to evaluate the comparative ability of the regression equations and process-based water quality models to estimate event diffuse pollutant loads from impervious surfaces. The results indicate that, once calibrated, both the regression equations and the process-based model can estimate event pollutant loads satisfactorily. In fact, the loads estimated using the regression equation as a function of rainfall intensity and runoff rate are better than the loads estimated using the process-based model. Therefore, if only estimates of event loads are required, regression models should be used because they are simpler and require less data compared to process-based models.

Reference ID 92

Pandit, A. and Gopalakrishnan, G. (1997). "Estimation of annual pollutant loads under wet-weather conditions." Journal of Hydrologic Engineering, 2(4): 211-218.

Keywords: continuous simulation, load modeling,

☒ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The Continuous Simulation Method (CSM) has been used to predict average annual total nitrogen storm-water loads, under wet-weather conditions, for various sites in Tampa, Florida. Predicted loads are compared to those predicted by other existing `spreadsheet' models, namely the Storm Water Management Model (SWMM) Level I - Preliminary Screening Procedure, the Simple Method, and the U.S. Geological Survey (USGS) Regression Model. Comparisons showed that the USGS Regression Model predictions were vastly different from those of the other models. The predictions by SWMM Level I, the Simple Method, and the CSM were closer, although there were substantial differences under certain conditions. Of the four models, the CSM provides the greatest flexibility to a model user; it has the capability to (1) model different soil types within a watershed; (2) model loading variations due to geographical (location) and demographic (land use and cover) differences between watersheds; and (3) simulate confidence intervals around the predicted average annual loads.

Reference ID 93

Zhang, J., Haan, C.T., Tremwel, T.K., and Kiker, G.A. (1995). "Evaluation of phosphorus loading models for South Florida." Transactions of the ASAE, 38(3), 767-773.

Keywords: CREAMS, phosphorus, pollutant loads, water quality

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Phosphorus enrichment poses a threat to the ecology of Florida's Lake Okeechobee. As a part of a phosphorus management program, the South Florida Water Management District evaluated two nutrient loading models - CREAMS-WT and FHANTM. Model documentation and algorithms were reviewed. Model simulations for phosphorus loading were compared to measured data for three sites for the period April 1989, through December 1991. Statistical correlation of monthly and annual values was analyzed. Based on these analyses, recommendations concerning the models for predicting phosphorus loading from Lake Okeechobee watersheds are presented.

Reference ID 94

Osborne, K.G. (2000). "A water quality GIS tool for the City of Austin incorporating non point sources and Best Management Practices." M.S. Thesis, University of Texas at Austin, Austin, TX, USA.

Keywords: GIS model, water quality, impervious surfaces, land uses

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Estimating pollution contributions from non-point sources is always difficult. Calculating pollution due to runoff into urban creeks and waterways is no exception. In an effort to model non point source pollution in Austin, a Geographic Information System (GIS) grid based hydrology model was developed for the City to aid in the development of a citywide Water Quality Master Plan. There are three primary objectives for the model: 1) compute current pollutant loadings for seventeen constituents at Environmental Integrity Index (EII) sites; 2) estimate future loadings for the year 2040 for the same constituents; and 3) model the influence of Best Management Practices (BMPs) on reducing pollution loads. Initial work completed in 1997 by researchers at the Center for Research in Water Resources (CRWR) was a substantive first step; however, many limitations and recommendations were also identified. This paper discusses the next manifestation of the model that was developed at CRWR during 1999-2000. The three main modifications made in the second phase concern increasing both model accuracy and accessibility. First, significant improvements were made to improve datasets used as input to the model. Second, corrections for both flow and load calculations were made on a cell-by-cell basis within the GIS environment instead of corrected separately in a spreadsheet. Third, future impervious cover projections, the basis for flow calculations, were tied more closely to undeveloped land parcels. Lastly, to make the model more accessible to a variety of policy makers, reliance on ArcInfo has been minimized; ArcView is now the platform for the model. In addition to these changes, new City assumptions were incorporated, especially with regards to base flow and storm flow separation. With these modifications in place, City objectives were met, and improvements in accuracy and accessibility were realized.

Reference ID 95

Pitt, R and Voorhees, J. (2002). SLAMM, the Source Loading and Management Model. in: Sullivan, D. and Field, R. (eds) Management of Wet-Weather Flow in the Watershed. CRC Press, Boca Raton, 1-32.

Keywords: loading model, water quality, SLAMM, small storm hydrology

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The Source Loading and Management Model (SLAMM) was originally developed to better understand the relationships between sources of urban runoff pollutants and runoff quality. It has been continually expanded since the late 1970s and now includes a wide variety of source area and outfall control practices (infiltration practices, wet detention ponds, porous pavement, street cleaning, catchbasin cleaning, and grass swales). SLAMM is strongly based on actual field observations, with minimal reliance on theoretical processes that have not been adequately documented or confirmed in the field. SLAMM is mostly used as a planning tool, to better understand sources of urban runoff pollutants and their control. Special emphasis has been placed on small storm hydrology and particulate washoff in SLAMM. Many currently available urban runoff models have their roots in drainage design where the emphasis is with very large and rare rains. In contrast, stormwater quality problems are mostly associated with common and relatively small rains. The assumptions and simplifications that are legitimately used with drainage design models are not appropriate for water quality models. SLAMM therefore incorporates unique process descriptions to more accurately predict the sources of runoff pollutants and flows for the storms of most interest in stormwater quality analyses. However, SLAMM can be effectively used in conjunction with drainage design models to incorporate the mutual benefits of water quality controls on drainage design. SLAMM has been used in many areas of North America and has been shown to accurately predict stormwater flows and pollutant characteristics for a broad range of rains, development characteristics, and control practices. As with all stormwater models, SLAMM needs to be accurately calibrated and then tested (verified) as part of any local stormwater management effort.

Reference ID 96

Pitt, R., Liburn, M., Durrans, S.R., Burian, S., Nix, S., Voorhees, J, and Martinson, J. (1999). The Integration of SWMM and SLAMM. in: Guidance Manual for Integrated Wet Weather Flow (WWF) Collection and Treatment Systems for Newly Urbanized Areas (New WWF Systems). USEPA Publication # 600/X-99/XXX

Keywords: SLAMM, SWMM, load modeling, continuous simulation,

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The use of computers has become common in many aspects of engineering practice, including wet weather management. In fact, no reasonable methodology can be conducted without the analytical and modeling capabilities of a computer. Unfortunately, no currently available software package adequately integrates wet weather quantity and quality objectives. This project will, however, develop such a package with the integration of two currently used computer models -- the EPA's Storm Water Management Model (SWMM) (Huber, et al. 1988) and the Source Loading and Management Model (SLAMM) (Pitt and Voorhees 1995). These two popular models have unique characteristics that when merged will create the kind of tool needed for effective wet weather management. The integrated model will form the principal analytical tool used in the

Reference ID 97

Valeo, C. and Moin, S.M.A. (2000). "Variable source area modeling in urbanizing watersheds." Journal of Hydrology, 228(1), 68-81.

Keywords: variable source areas, TOPMODEL, hydrologic modeling, GIS

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

A variable source area model called TOPMODEL was modified and tested for its applicability on urbanizing watersheds. The model was modified to consider urban land uses by altering the topographic index and the mechanism of surface runoff generation. A Geographic Information System was utilized to delineate the catchment, determine the urban areas and produce Digital Elevation Models. The model was applied to a small catchment of approximately 8 km2 in southern Ontario that is characterized by mild slopes, well-draining soils and a semi-humid climate. Testing was conducted using a partially revised model with four calibration parameters (TOPURBAN v. 1) applied to three separate time periods; and a fully revised model with five calibration parameters (TOPURBAN v. 2) applied to six time periods. The model performed well with calibrated model efficiencies of greater than 70%. Verification efficiencies ranged from 20 to 70%. TOPURBAN v. 2 increased Nash and Sutcliffe efficiency in comparison to v. 1 by anywhere from 2 to 8% as it accounted for storage in the urban areas. This model is recommended for urbanizing catchments of small to moderate size. Some calibrated parameter interaction was observed between parameters dealing with the urban areas and parameters dealing with the natural areas.

Reference ID 98

Al-Abed, N.A. and Whiteley, H.R. (2002). "Calibration of the Hydrologic Simulation Program Fortran model using calibration and geographic information systems." Hydrological Processes, 16, 3169-3188.

Keywords: HSPF, hydrologic model, GIS, subsurface flow,

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Calibrating a comprehensive, multi-parameter conceptual hydrological model, such as the Hydrological Simulation Program Fortran model, is a major challenge. This paper describes calibration procedures for water-quantity parameters of the HSPF version 10%; 11 using the automatic-calibration parameter estimator model coupled with a geographical information system (GIS) approach for spatially averaged properties. The study area was the Grand River watershed, located in southern Ontario, Canada, between 79 degree 30' and 80 degree 57'W longitude and 42 degree 51' and 44 degree 31'N latitude. The drainage area in 6965 km super(2). Calibration efforts were directed to those model parameters that produced large changes in model response during sensitivity tests run prior to undertaking calibration. A GIS was used extensively in this study. It was first used in the watershed segmentation process. During calibration, the GIS data were used to establish realistic starting values for the surface and subsurface zone parameters LZSN, UZSN, COVER, and INFILT and physically reasonable ratios of these parameters among watersheds were preserved during calibration with the ratios based on the known properties of the subwatersheds determined using GIS. This calibration procedure produced very satisfactory results; the percentage difference between the simulated and the measured yearly discharge ranged between 4 to 16%, which is classified as good to very good calibration. The average simulated daily discharge for the watershed outlet at Brantford for the years 1981-85 was 67 m super(3) s super(-1) and the average measured discharge at Brantford was 70 m super(3) s super(-1). The coupling of a GIS with automatice calibration produced a realistic and accurate calibration for the HSPF model with much less effort and subjectivity than would be required for unassisted calibration.

Reference ID 99

Tsihrintzis, V.A., Fuentes, H.R., and Gadipudi, R.K. (1997). "GIS-aided modeling on nonpoint source pollution impacts on surface and ground Waters." Water Resources Management, 11, 207-218.

Keywords: geographic information systems (GIS) - HSPF - modeling - surface water - ground water - nonpoint source pollution - agricultural pollution - urban pollution - pollution prevention

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☒ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

An application of GIS-aided modeling is done at an area in South Florida. A Geographic Information System (GIS) is interfaced with a nonpoint source pollution model to facilitate data storage, management and display; derivation of model input parameters; and effective presentation of results. parameters, and to visually present results in maps. Results for current conditions and practices show that sediments, nutrients and pesticides are present in surface runoff and ground water. Two alternatives to minimize pollution levels are evaluated, i.e., reduction of fertilizer application to the minimum required for effective agricultural growth and replacement of fertilizers with sewage sludge.

Reference ID 100

Abu-Zreig, M., Rudra, R.P. and Whiteley, H.R. (2001). "Validation of a vegetated filter strip model (VFSMOD)." Hydrol. Process. 15(5): 729-742.

Keywords: process-based model, vegetated filter strips, biofilters, stormwater treatment

☐ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Vegetated filter strips (VFS) are designed to reduce sediment load and other pollutants into water bodies. However, adaptation of VFS in the field has been limited owing to lack of data about their efficiency and performance under natural field conditions. A number of models are available that simulate sediment transport and trapping in VFS, but there is a general lack of confidence in VFS models owing to limited validation studies and model limitations that prevent correct application of these models under field conditions. The objective of this study is to test and validate a process-based model (VFSMOD) that simulates sediment trapping in VFS. This model links three submodels: modified Green-Ampt's infiltration, Quadratic overland flow submodel based on kinematic wave approximation and University of Kentucky sediment filtration model. A total of 20 VFS, 2, 5, 10 and 15 m long and with various vegetation covers, were tested under simulated sediment and runoff conditions. The results of these field experiments were used to validate the VFS model. The model requires 25 input parameters distributed over five input files. All input parameters were either measured or calculated using experimental data. The observed sediment trapping efficiencies varied from 65% in the 2-m long VFS to 92% in the 10-m long filters. No increase in sediment removal efficiency was observed at higher VFS length. Application of the VFS model to experimental data was satisfactory under the condition that actual flow widths are used in the model instead of the total filter width. Predicted and observed sediment trapping efficiencies and infiltration volume fitted very well, with a coefficient of determination (R super(2)) of 0.9 and 0.95, respectively. Regression analyses revealed that the slope and intercept of the regression lines between predicted versus observed infiltration volume and trapping efficiency were not significantly different than the line of perfect agreement with a slope of 1.0 and intercept of 0.0.

Reference ID 101

Frankenberger, J.R., Brooks, E.S., Walter, M.T., Walter, and M.F., Steenhuis, T.S. (1999). "GIS-based variable source area hydrology model." Hydrological Processes, 13(6), 805-822.

Keywords: GIS, variable source areas, water balance, GRASS

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Effective control of nonpoint source pollution from contaminants transported by runoff requires information about the source areas of surface runoff. Variable source hydrology is widely recognized by hydrologists, yet few methods exist for identifying the saturated areas that generate most runoff in humid regions. The Soil Moisture Routing model is a daily water balance model that simulates the hydrology for watersheds with shallow sloping soils. The model combines elevation, soil, and land use data within the geographic information system GRASS, and predicts the spatial distribution of soil moisture, evapotranspiration, saturation-excess overland flow (i.e., surface runoff), and interflow throughout a watershed. The model was applied to a 170 hectare watershed in the Catskills region of New York State and observed stream flow hydrographs and soil moisture measurements were compared to model predictions. Stream flow prediction during non-winter periods generally agreed with measured flow resulting in an average r² of 0.73, a standard error of 0.01 m³/s, and an average Nash-Sutcliffe efficiency R² of 0.62. Soil moisture predictions showed trends similar to observations with errors on the order of the standard error of measurements. The model results were most accurate for non-winter conditions. The model is currently used for making management decisions for reducing non-point source pollution from manure spread fields in the Catskill watersheds which supply New York City's drinking water.

Reference ID 102

Dartiguenave, C.M. and Maidment, D.R. (1997). "Water Quality Master Planning for Austin." Center for Research in Water Resources (CRWR), Online Report 97-6.

Keywords: pollutant loads, GIS, watershed master plan, land use EMCs

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The goal of this research is the creation of a non-point source pollution water quality model using a Geographic Information System. The area chosen for the study is the City of Austin, which partly overlays the recharge zone of the Edwards Aquifer. A model based on raster data that takes into account the presence of the recharge zone was created both in ArcView and in Arc/Info for mean annual flows and pollutant loadings. The model is able to perform the following tasks: 1) compute current pollutant loadings for TSS, BOD, COD, TOC, DP, TP, NH3, TKN, NO3, TN, Cu, Pb and Zn, 2) compute future loadings for the year 2040 for the same constituents, 3) model the effect of located and regional Best Management Practices. The model was designed so that it could deal with different sets of input parameters and locations.

Reference ID 103

Melancon, P.A., Maidment, D.R., and Barrett, M.E. (1999). "A GIS Based Watershed Analysis System for Tillamook Bay, Oregon." Center for Research in Water Resources (CRWR), Online Report 99-3

Keywords: GIS, load model, stormwater BMPs, land use, EMCs

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The goal of this research is to develop a GIS based watershed scale water quality model of the Tillamook Bay watershed on the coast of Oregon that can be used as a decision support system. A method is developed using a Geographic Information Systems (GIS) platform, specifically Arc/Info and ArcView. A 100 foot grid digital elevation model is used to establish connectivity within the watershed. Raster maps of runoff and baseflow are determined from a raster map of annual precipitation. Non-point source loads of bacteria and sediment are determined for each grid cell as the product of discharge and expected mean concentration (EMC). EMC values are based on land use. These non-point loads are accumulated down to the bay segments. Point source loads from wastewater treatment plant effluent have been included in the model. Implementation of Best Management Practices (BMPs) result in load reductions on a per cell basis. These reductions are based on user input data related to BMP effectiveness and level of implementation. Predicted concentration grids are calculated based on accumulated loads and flows. Tools are available to determine: (1) loads, flows, and resultant concentrations at points of interest, (2) percent reduction of load to each bay segment as a result of BMP implementation, and (3) constituent concentration profiles along the length of a river. Predicted flows and concentrations reasonably match values reported in earlier studies. Model results indicate that the majority of the bacteria load comes from dairy lands, and sediment loads appear to be strongly linked to channel erosion processes, particularly in the lowland river reaches.

Reference ID 104

Tong, S.T.Y and Chen, W. (2002). "Modeling the relationship between land use and surface water quality." Journal of Environmental Management, 66, 377-393.

Keywords: BASINS, load modeling, land use, ArcView, watershed hydrologic modeling, water quality, flow

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

It is widely known that watershed hydrology is dependent on many factors, including land use, climate, and soil conditions. But the relative impacts of different types of land use on the surface water are yet to be ascertained and quantified. This research attempted to use a comprehensive approach to examine the hydrologic effects of land use at both a regional and a local scale. Statistical and spatial analyses were employed to examine the statistical and spatial relationships of land use and the flow and water quality in receiving waters on a regional scale in the State of Ohio. Besides, a widely accepted watershed-based water quality assessment tool, the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), was adopted to model the plausible effects of land use on water quality in a local watershed in the East Fork Little Miami River Basin. The results from the statistical analyses revealed that there was a significant relationship between land use and in-stream water quality, especially for nitrogen, phosphorus and Fecal coliform. The geographic information systems (GIS) spatial analyses identified the watersheds that have high levels of contaminants and percentages of agricultural and urban lands. Furthermore, the hydrologic and water quality modeling showed that agricultural and impervious urban lands produced a much higher level of nitrogen and phosphorus than other land surfaces. From this research, it seems that the approach adopted in this study is comprehensive, covering both the regional and local scales. It also reveals that BASINS is a very useful and reliable tool, capable of characterizing the flow and water quality conditions for the study area under different watershed scales. With little modification, these models should be able to adapt to other watersheds or to simulate other contaminants. They also can be used to study the plausible impacts of global environmental change. In addition, the information on the hydrologic effects of land use is very useful. It can provide guidelines not only for resource managers in restoring our aquatic ecosystems, but also for local planners in devising viable and ecologically-sound watershed development plans, as well as for policy makers in evaluating alternate land management decisions.

Reference ID 105

Driver, N.E., and Tasker, G.D. (1990). "Techniques for Estimation of Storm-Runoff Loads, Volumes, and Selected Constituent Concentrations in Urban Watersheds in the United States." U.S. Geological Survey Water-Supply Paper # 2363.

Keywords: regression based modeling, watershed-scale modeling, load modeling

☒ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Urban planners and managers need information on the quantity of precipitation and the quality and quantity of run off in their cities and towns if they are to adequately plan for the effects of storm runoff from urban areas. As a result of this need, four sets of linear regression models were developed for estimating storm-runoff constituent loads, storm-runoff volumes, storm-runoff mean concentrations of constituents, and mean seasonal or mean annual constituent loads from physical, land-use, and climatic characteristics of urban watersheds in the United States. Thirty-four regression models of storm-runoff constituent loads and storm-runoff volumes were developed, and 31 models of storm-runoff mean concentrations were developed . Ten models of mean seasonal or mean annual constituent loads were developed by analyzing long-term storm-rainfall records using at-site linear regression models.

Three statistically different regions, delineated on the basis of mean annual rainfall, were used to improve linear regression models where adequate data were available . Multiple regression analyses, including ordinary least squares and generalized least squares, were used to determine the optimum linear regression models . These models can be used to estimate storm-runoff constituent loads, storm-runoff volumes, storm-runoff mean concentrations of constituents, and mean seasonal or mean annual constituent loads at gaged and ungaged urban watersheds.

The most significant explanatory variables in all linear regression models were total storm rainfall and total contributing drainage area. Impervious area, land-use, and mean annual climatic characteristics also were significant in some models. Models for estimating loads of dissolved solids, total nitrogen, and total ammonia plus organic nitrogen as nitrogen generally were the most accurate, whereas models for suspended solids were the least accurate. The most accurate models were those for application in the more arid Western States, and the least accurate models were those for areas that had large mean annual rainfall.

Reference ID 106

Kalin, L., and Hantush, M.M. (2003). "Evaluation of sediment transport models and comparative application of two watershed models." USEPA Publication #600/R-03/139.

Keywords: suspended sediment, sediment transport, load modeling, stormwater BMPs, SWMM, SWAT, AGNPS, HPSF

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☒ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Suspended solids and sediments are regarded as the two leading pollutants of nation's streams and waterbodies. They serve as carriers for various pesticides, radioactive materials and nutrients. Section 303(d) of the 1972 Clean Water Act requires states, territories, and authorized tribes to identify and list impaired waters every two years and to develop Total Maximum Daily Loads (TMDLs) for pollutants in these waters. Mathematical models are widely accepted, effective and powerful tools for TMDL development, and evaluating performances of Best Management Practices (BMP). The rapid pace of computer technology has been a milestone for mathematical models in hydrology, hydrodynamics and recently water quality. The high demand on computer models resulted in development of many models and placed a new burden on model users, that is model selection. The selection of the right model under certain constraints requires a comprehensive knowledge of the capabilities and features of available models. This report provides an overview and evaluation of sediment models and compares two distributed, watershed scale models by application to an experimental watershed. A probabilistic, risk-based mathematical optimization framework is presented and proposed as a strategy for solving the TMDL-BMP problem involving multiple stressors in feature endeavors. Future modeling efforts may benefit from exploring the use of system analysis approaches to obtain cost-effective, optimal load reductions using BMPs.

The report is comprised of two parts. The first part evaluates and summarizes some of the key features of the most widely cited watershed scale, hydrodynamic and water quality models with the emphasis on TMDLs and BMPs. Reviewed models were selected based on minimum criteria. Water quality models, specifically those that can simulate nutrients in the environment are also considered since transport and fate of sediments and nutrients are intimately related phenomena. Among the reviewed loading models SWAT and AGNPS offer the most BMP alternatives at agricultural watersheds. For urban areas SWMM, and for mixed land uses, i.e. rural and urban, HSPF are identified as the most suitable loading models. These models need to be used with hydrodynamic and water quality models for a complete TMDL analysis and BMP development. BASINS and MIKE-SHE are comprehensive watershed-water quality modeling systems, with varying degrees of complexity. WMS offers a tractable watershed-modeling platform if fully developed can be used for sediment TMDLs allocation. Available and potential model linkages between loading, hydrodynamic and water quality models are also discussed. It is observed that most physically based models are incapable for a complete BMP assessment. As a future need in modeling, enhancement of such models to simulate more BMPs is recommended along with development of more linkages between loading and hydrodynamic/water quality models.

The second part of the report evaluates, by application to an experimental watershed, two promising distributed watershed-scale sediment models in detail: KINEROS-2 and GSSHA. Sensitivity of KINEROS-2 to model parameters was evaluated within a probabilistic framework using Monte Carlo simulations to identify key model parameters for calibration. It was shown that the order of parameter sensitivities changes with the quantity of interest (peak flow, total sediment yield, etc.). The calibration/verification procedure performed over KINEROS-2 has shown that the Manning's roughness and soil erosion parameters show systematic seasonal variations. Both models were calibrated and verified and the results clearly highlight the challenges modelers face when applying complex, distributed watershed models. The results are discussed and compared. They highlight the importance for numerical application of different watershed models to gauged watersheds as means for models evaluation. Future efforts aiming at the evaluation of hydrologic and water quality models should migrate from qualitative analysis to actual comparative applications to real case studies.

Reference ID 107

Srivastava, P., Hamlett, J.M., and Robillard, P.D. (2003). "Watershed optimization of agricultural best management practices: Continuous simulation versus design storms." Journal of the American Water Resources Association, 39(5), 1043-1054.

Keywords: continuous simulation, design storm, BMP optimization, non-point source pollutants

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Nonpoint source (NPS) models and expert opinions are often used to prescribe best management practices (BMPs) for controlling NPS pollution. An optimization algorithm (e.g., a genetic algorithm, or GA) linked with a NPS model (e.g., Annualized AGricultural Nonpoint Source pollution model, or AnnAGNPS), can be used to more objectively prescribe BMPs and to optimize NPS pollution control measures by maximizing pollutant reduction and net monetary return from a watershed. Pollutant loads from design storms and annual loads from a continuous simulation can both be used for optimizing BMP schemes. However, which strategy results in a better solution (in terms of providing water quality protection) for a watershed is not clear. The specific objective of the study was to determine the differences in watershed pollutant loads, in an experimental watershed in Pennsylvania, resulting from optimization analyses performed using pollutant loads from a series of five 2-yr 24-hr storm events, a series of five 5-yr 24-hr storm events, and cumulative pollutant loads from a continuous simulation of five years of weather data. For each of these three different event alternatives, 100 near optimal solutions (BMP schemes) were generated. Sediment (Sed), sediment nitrogen (SedN), dissolved N (SolN), sediment organic carbon (SedOC), and sediment phosphorus (SedP) loads from a different five-year period (an evaluation period) suggest that the optimal BMP schemes resulting from the use of annual cumulative pollutant loads from a continuous simulation of five years of weather data provide smaller cumulative NPS pollutant loads at the watershed outlet.

Reference ID 108

Quenzer, A.M. (1998). "A GIS assessment of the total loads and water quality in the Corpus Christi Bay system." Center for Research in Water Resources (CRWR), Online Report 98-1.

Keywords: GIS Model Comparisons, GLEAMS, HSPF, STORM

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

A method is presented for determining raster maps of mean annual water flow and pollutant loading from the land surface, and for determining the resulting concentrations in receiving water bodies. The method is illustrated by application to the Corpus Christi Bay system in South Texas. A mesh of 100m digital elevation model cells is laid over the drainage area and cell to cell connectivity established to link each land surface cell with a corresponding water body segment. Non-point source constituent loads are determined for each cell as the product of runoff and expected mean concentration, and accumulated down to the bay system. Point source and atmospheric loads are added, water quality computed in each bay system, and compared to observed data. A strong South to North runoff gradient is observed in the study area. The majority of the constituent loading comes from non-point sources, except for oil and grease, which arise mainly from point sources. Nitrogen and phosphorus concentrations in the bay system are reproduced reasonably well provided a decay rate of 0.01-0.02 day-1 is used. Oil and grease are reproduced well as conservative constituents. The computed metals concentrations are low and suggest a significant source in sediment or elsewhere that is presently not accounted for.

Reference ID 109

Chui, T.W., Mar, B.W., and Horner, R.R. (1982). "Pollutant loading model for highway runoff." ASCE Journal of the Environmental Engineering, 108(6), 1193-1210.

Keywords: Highway Runoff, TSS as Surrogate, Land-Use

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

A stormwater runoff pollutant loading model has been developed on the basis of results from composite sampling of approximately 500 storms at nine locations in Washington State. One component of the model is an expression for total suspended solids (TSS) load in relation to traffic, runoff coefficient, and surrounding land use contributions. Other contaminants are estimated from TSS load using ratios derived from the data.

Reference ID 110

Zug, M., Phan, L., Bellefleur, D., and Scrivener, O. (1999). "Pollution wash-off modeling on impervious surfaces: calibration, validation, transposition." Water Science and Technology, 39(2), 17-24.

Keywords: build up/wash off, sediment transport, load model, SWMM

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

This paper presents the modification and the application of the conceptual wash-off model initially proposed by the SWMM on five separate urban catchments with very different characteristics and during a lot of rainfall events. To allow measurements on real sites to be considered, this model was incorporated in an overall model including simulation build-up, sediment transport in collector as well as runoff and hydraulics. This modified model has been calibrated, validated, transposed and completed with sensivity analysis of parameters and initial conditions. The proposed model gives some improvement to the results of the initial model: an adaptation to a large range of rainfalls, the correct reproduction of the peak values and satisfying reproduction of the beginning and the end of the TSS pollutograph.

Reference ID 111

Deletic, A., Maksimovic, C., and Ivetic, M. (1997). "Modeling of storm wash-off of suspended solids from impervious surfaces." Journal of Hydraulic Research, 35(1), 99-118.

Keywords: build up/wash off, impervious surfaces, continuous simulation, load modeling

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

A mathematical model of suspended solids discharge from impervious surfaces during storm events has been developed. The model continuously simulates two major processes of different time scales; solids build-up at impervious surfaces between two storm events, and solids wash-off from the surfaces during storm events. Build-up is modelled using the Sartor and Boyd equation (21) in which the amount of solids available on the surface is an exponential function of antecedent dry weather period duration. The spatial distribution of solid particles over the street surface is also modelled, which is an innovation. The wash-off process is divided into three sub-processes that are modelled consecutively. A kinematic wave model is used for overland flow modelling. The particle entrainment into suspension is estimated by two methods. In one, the rainfall and overland flow effects are not separated and the total shear stress is used to predict entrainment. In the other, the rainfall and overland flow effects are treated separately and then summed. An original equation was developed for this method. The model is applied on two small experimental catchments, one at Miljakovac-Belgrade, Yugoslavia and the other in Lund, Sweden. The description and verification of the model are presented and discussed in the paper.

Reference ID 112

Winter, J.G. and Duthie, H.C. (2000). "Export coefficient modeling to assess phosphorus loading in an urban watershed." Journal of the American Water Resources Association, 36(5), 1053-1061.

Keywords: land use, export coefficient, phosphorus, BMP assessment

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

An export coefficient modeling approach was used to assess the influence of land use on phosphorus loading to a Southern Ontario stream. A model was constructed for the 1995-1996 water year and calibrated within 3 percent of the observed mean concentration of total phosphorus. It was found that runoff from urban areas contributed most to the loading of phosphorus to the stream. When the model was assessed by running it for the 1977-1978 water year, using water quality and land use data collected independently, agreement within 7 percent was obtained. The model was then used to forecast the impact of future urban development proposed for the watershed, in terms of phosphorus loading, and to evaluate the reduction in loading resulting from several urban best management practices (BMP). It was determined that phosphorus removal will have to be applied to all the urban runoff from the watershed to appreciably reduce stream phosphorus concentration. Of the BMP designs assessed, an infiltration pond system resulted in the greatest phosphorus load reduction, 50 percent from the 1995-1996 baseline.

Reference ID 113

Mishra, S.K., Jain, M.K., and Singh, V.P. (2004). "Evaluation of the SCS-CN-based model incorporating antecedent moisture." Water Resources Management, 18, 567-589.

Keywords: SCS Curve Number, hydrologic model, antecedant moisture conditions,

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Using a large set of rainfall-runoff data from 234 small to large watersheds from USA, this paper evaluates the modified version of the [Mishra, S. K. and Singh, V. P., 2002a, ‘SCS-CN-based hydrologic simulation package’, in V. P. Singh and D. K. Frevert (eds), Mathematical Models in Small Watershed Hydrology, Water Resources Publications, Chap. 13, pp. 391–464] (MS) model which is based on the Soil Conservation Service Curve Number (SCS-CN) methodology and incorporates the antecedent moisture in direct surface runoff computations. Comparison with the existing SCS-CN method using the t-test and the ranking-based grading shows that the modified MS model performs far better than the existing SCS-

Reference ID 114

Ferguson, B.K. (1996). "Estimation of direct runoff in the Thornwaite water balance." Professional Geographer, 48(3), 263-

Keywords: Thornthwaite, water balance, SCS curve number, hydrologic model

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Estimates the monthly direct runoff in the Thornthwaite water balance. Benefits of including direct runoff in water balance analysis; Evaluation of the model of monthly direct runoff by comparing with daily calculation using the Soil Conservation Service (SCS) method.

Reference ID 115

Newman, T.L. II, Omer, T.A., and Driscoll, E.D. (1999). SWMM storage-treatment for analysis/design of extended-detention ponds. in: Applied Modeling of Urban Water Systems, Monograph 8 in a Series. Proc. of the Conference on Stormwater and Urban Water Systems Modeling Toronto, Ontario, February 18-19, 1999.

Keywords: SWMM, extended detention basins, pollutant removal, stormwater BMPs

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

This paper describes the application of the Storage-Treatment (S-T) Block of the EPA Storm Water Management Model (SWMM) to design and/or analyze Extended-Detention Ponds (EDPs) for the reduction of pollutant loads from storm-water runoff. SWMM simulation results, supported with simple spreadsheet models, are presented to illustrate the influence of design features on expected pollutant-removal efficiency of this popular best-management practice (BMP). Important insights on the operational characteristics of EDPs are also provided, based on sensitivity analyses that were performed to evaluate certain alternative design features in actual case studies. The importance of this refined method for EDP design is emphasized with examples of how the use of common rules of thumb or guidelines from BMP manuals could result in unexpectedly poor EDP performance.

Reference ID 116

Jain, M.K., Kothyari, U.C., and Ranga Raju, K.G. (2004). "A GIS-based distributed rainfall-runoff model." Journal of Hydrology, 299, 107-135.

Keywords: GIS, Phillip Infiltration, Rainfall-Runoff

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

A grid or cell based process oriented distributed rainfall-runoff model capable of handling the catchment heterogeneity in terms of distributed information on landuse, slope, soil and rainfall is developed and applied to isolated storm events in several catchments. Model inputs such as slope, flow direction and overland flow sequencing (drainage path) are generated for each cell of the catchment using a digital elevation model and information about landuse, soil, etc. were derived through digital analysis of satellite data and published information. The input variables for each cell area are provided to the model through geographic information system. Infiltration in cell areas is computed by Philip two-term infiltration model, the parameters of which were determined mainly through the information on soil type in the cell. The mechanics of overland flow is described by the diffusion wave approximation of St Venant equations which are numerically solved for depth of flow and runoff by the method of finite volume. The model utilizes a relationship explaining the dependence of flow resistance on depth of flow and surface roughness. Results from several catchments indicate that the model can simulate reasonably well the runoff hydrograph at the catchment outlet. The model also realistically predicts temporal variation of the spatial distribution of flow depth and runoff over the catchment. Also the grid or cell based structure of the model allows studying the effect of catchment modifications in terms of soil and landuse changes on spatial and temporal distribution of the runoff. However, the proposed model has the limitation that the values of some parameters of the model need to be obtained through calibration.

Reference ID 117

Steenhuis, T.S., Winchell, M., Rossing, J., Zollweg, J.A., and Walter, M.F. (1995). "SCS runoff equation revisited for variable-source runoff areas." Journal of Irrigation and Drainage Engineering, 121(3), 234-238.

Keywords: soil moisture, SCS method, variable source area, GRASS, GIS, daily water balance

☐ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Effective control of nonpoint source pollution from contaminants transported by runoff requires information about the source areas of surface runoff. Variable source hydrology is widely recognized by hydrologists, yet few methods exist for identifying the saturated areas that generate most runoff in humid regions. The Soil Moisture Routing model is a daily water balance model that simulates the hydrology for watersheds with shallow sloping soils. The model combines elevation, soil, and land use data within the geographic information system GRASS, and predicts the spatial distribution of soil moisture, evapotranspiration, saturation-excess overland flow (i.e., surface runoff), and interflow throughout a watershed. The model was applied to a 170 hectare watershed in the Catskills region of New York State and observed stream flow hydrographs and soil moisture measurements were compared to model predictions. Stream flow prediction during non-winter periods generally agreed with measured flow resulting in an average r² of 0.73, a standard error of 0.01 m³/s, and an average Nash-Sutcliffe efficiency R² of 0.62. Soil moisture predictions showed trends similar to observations with errors on the order of the standard error of measurements. The model results were most accurate for non-winter conditions. The model is currently used for making management decisions for reducing non-point source pollution from manure spread fields in the Catskill watersheds which supply New York City's drinking water.

Reference ID 118

Singh, J., Knapp, H.V., and Demissie, M. (2004). "Hydrologic modeling of the Iroquois River watershed using HSPF and SWAT." Illinois State Water Survey Contract Report 2004-08.

Keywords: HSPF, SWAT, BASINS, hydrologic model, average daily, average monthly, annual stream flows

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Watershed scale hydrologic simulation models HSPF (Hydrologic Simulation Program (FORTRAN) and SWAT (Soil and Water Assessment Tool) were used to model the hydrology of the 2150 square mile Iroquois River watershed (IRW) located in the east central Illinois. Both models are part of the BASINS modeling system that facilitates pre- and post-processing of data, as well as data input to the models using an ArcView GIS interface and GUI. HSPF has been widely used for different watersheds all over the US. SWAT was added to BASINS in 2001 and is currently under evaluation. Based on the completeness of the meteorological data, a nine year period of 1987-1995 is used for model calibration, and a 15-year period of 1972-1986 for model validation. Time series plots as well as statistical measures such as Nash-Sutcliffe efficiency (NSE), coefficient of correlation (r), and the percent volume error between observed and simulated streamflow values on both monthly and annual bases were used to verify the simulation abilities of the models. Calibration and validation results from both HSPF and SWAT show that the models generally predict daily, and average monthly and annual stream flows close to the respective observed stream flows.

Reference ID 119

Shammaa, Y., Zhu, D.Z., Gyurek, L.L., and Labatiuk, C.W. (2002). "Effectiveness of dry ponds for stormwater total suspended solids removal." Canadian Journal of Civil Engineering, 29(2): 316-324.

Keywords: empirical method, detention pond performance, stormwater BMPs, dry pond, stormwater, TSS removal, detention time, retrofitting

☐ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

his paper reviews the factors and criteria for the design of new and the retrofitting of existing dry detention ponds to enhance removal of total suspended solids (TSS) from stormwater. Detention time is discussed as the most important factor affecting TSS removal. Two-stage facilities and multi-level outlet design are important means of enhancing TSS removal in dry ponds. Two dry ponds within the city of Edmonton were selected to evaluate their TSS removal. The level of expected TSS removal is low owing to the relatively short detention times for both ponds. Methods for retrofitting the dry ponds to enhance TSS removal are discussed.

Reference ID 120

Cassell, E.A. and Clausen, J.C. (1993). "Dynamic simulation modelling for evaluating water quality response to agricultural BMP implementation." Water Science and Technology, 28(3-5), 635-648.

Keywords: phosphorus, agriculture, nutrient model,

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Dynamic simulation modelling (DSM) is a computer modelling technique that promotes description of complex natural systems, such as watersheds and BMP systems. When DSM is accomplished in an object oriented programming framework, modelling is highly interactive. The Field Phosphorus Model (FPM) was created with STELLA^(R) II, an object oriented DSM programming environment. FPM is based on sophisticated accounting of all annual inputs and outputs of phosphorus for a farm field and simulates, on a yearly basis, patterns of phosphorus export from farm fields used for manure management on dairy farms. Model inputs include atmospheric deposition, manure application and chemical fertilizer; outputs include surface runoff, crop harvest, and movement into deeper soil layers. Using two BMP scenarios, the implications for long-term phosphorus export levels from the field to surface and ground waters are discussed. Changes in the land treatment or BMP levels on the field results in a lag time between when the BMP is implemented and when the full impact on phosphorus export is seen. The Field Phosphorus Model suggests that the simultaneous reduction of long-term phosphorus output to surface and ground waters is accomplished by implementation of BMP's that limit the input of phosphorus to the field.

Reference ID 121

Whittemore, R. and Ice, G. (1999). "Models for evaluating water quality and BMP effectiveness at the watershed scale." International Association of Hydrological Sciences (IAHS) Publication, 257, 265-271

Keywords: BASINS, DHSVM, BOISED, BMP performance, watershed scale, load modeling

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Water resource agencies have identified the need to develop watershed-scale assessments to evaluate progress in meeting the goals of the Clean Water Act. EPA's Watershed Initiative exemplifies this new focus. The forestry community has been a leader in developing these watershed evaluation techniques. Three distinct approaches are discussed and examples are provided. These include large watershed-scale monitoring, watershed-scale adaptive management assessments, and watershed modeling/monitoring combinations.

Large watershed monitoring differs from site-specific or small watershed monitoring in the critical treatment of transport and fate monitoring. Often, these studies involve measurement of tributaries and multiple reach response.

Adaptive management approaches are designed to learn from ongoing management. One well-accepted adaptive management approach, Watershed Analysis, is a structured procedure for examining watershed conditions, landscape and management hazards, and aquatic resources at risk. Another adaptive management approach for watersheds is the Source Search Method. This can involve a synoptic survey to identify "hot spots" associated with specific management and site condition combinations.

One of the most appealing approaches is the development of realistic models. Models can be used to test different alternatives and are not confounded by the weather or watershed variability associated with even well-paired adjacent basins. The development of calibration and validation data sets is critical to making models effective. Some examples of watershed-scale models used in assessing water quality response include DHSVM, BOISED, and BASINS2.

These examples demonstrate that modeling and monitoring should be coordinated to efficiently assess BMPs at the watershed scale.

Reference ID 122

Park, S.W., Mostaghimi, S., Cooke, R.A., and McClellan, P.W. (1994). "BMP impacts on watershed runoff, sediment, and nutrient yields." Water Resources Bulletin, 30(6), 1011-1023.

Keywords: BMP performance, SCS curve number, sediment transport, Runoff, Sediment yield, Nutrients, Watershed management

☐ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

To quantify the effectiveness of best management practice (BMP) implementation on runoff, sediment, and nutrient yields from a watershed, the Nomini Creek watershed and water quality monitoring project was initiated in 1985, in Westmoreland County, Virginia. The changes in nonpoint source (NPS) loadings resulting from BMPs were evaluated by comparing selected parameters from data series obtained before, during, and after periods of BMP implementation. The results indicated that the watershed averaged curve number, sediment, and nutrient (N and P) concentrations were reduced by approximately 5, 20, and 40 percent, respectively, due to BMP implementation. The nutrient yield model developed by Frere et al. (1980) was applied to the water quality parameters from 175 storms, but it failed to adequately describe the observed phenomena. Seasonal changes in nutrient availability factors were not consistent with field conditions, nor were they significantly different in the pre- and post-BMP periods. An extended period of monitoring, with intensive BMP implementation over a larger portion of the watershed, is required to identify BMP effectiveness.

Reference ID 123

Xue, R.Z., Bechtel, T.J., and Zhenquen, C. (1996). "Developing a user-friendly tool for BMP assessment model using GIS." Proc: AWRA Symposium on GIS and water resources, Sept 22-26, Ft. Lauderdale, FL.

Keywords: BMP; pre-processor; post-processor; pollutant loads; modeling; watershed management

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Best management practices (BMPs) have been applied widely in agricultural and urban areas to minimize stormwater runoff and associated pollution problems. Currently, the effectiveness of BMPs is evaluated mainly based on limited field data for similar types of BMPs and can only serve as a preliminary evaluation. A model based on runoff and pollutant removal mechanisms is needed to assess BMP performance in a more precise manner. We developed a mechanism-based Best Management Practices Assessment Model (BMPAM) to accomplish this goal. This model was further linked to a geographic information system (GIS) platform using ArcView version 2.1 software. An user-friendly interface was developed to improve the efficiency of analyses of stormwater management plans for decision makers and researchers. The integrated GIS tool consists of a pre-processor, a running module, and a post-processor. This paper describes the development of the linkage (using the ArcView macro language, AVENUE) between data coverages, BMP modeling, and data pre- and post-processing. An example BMP assessment simulation is presented to demonstrate the potential uses and capabilities of this integrated GIS tool.

Reference ID 124

Attanasio, R. and Danicic, D. (1994). "Comparing Three Stormwater Pollutant Load Models." Public Works, April

Keywords: pollutant loads, SWMM, simple method, P8

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The results of annual, dry season, and wet season stormwater pollutant load modeling using three different models were evaluated and compared. All three models were calibrated using the same hydrologic, meteorologic, and pollutant sample data. The three models are: the EPA Simple Method - a static model using a variation of the rational method coupled with event mean sample data used to estimate pollutant loading; P8 - a continuous simulation model used to predict the generation and transport of urban stormwater pollutants; and the SWMM runoff module - a continuous simulation model used to provide a comprehensive platform for urban quantity and quality simulation in stormwater and combined sewer.

Reference ID 125

Ohrel, R.L. (2000). "Simple and Complex Stormwater Pollutant Load Models Compared." In The Practice of Watershed Protection, Schueler, T.R. and Holland, H.K., eds., Center for Watershed Protection, Ellicott City, MD.

Keywords: simple method, SWMM, load modeling, pollutant transport

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

The Simple Method and computer model results were compared by computing a maximum ratio for various parameters. The maximum ratio represents the largest ratio between the simple and complex model pollutant load and runoff volume estimates. The maximum ratio is always greater than or equal to one; the larger of the two estimates being compared (i.e., the Simple Method or the computer model estimate) is always in the numerator. Positive values indicate that the computer model estimate was larger than the corresponding Simple Method estimate. Negative values indicate that the Simple Method estimate was larger than the computer model estimate. For example, in a given scenario the annual runoff volume estimate generated by SWMM is 83,000 acre-ft and the Simple Method estimate is 68,000 acre-ft. The maximum ratio value (the larger computer model estimate/the smaller Simple Method estimate) is approximately 1.22. Since the computer model estimate is the higher value, the ratio is positive.
The key to choosing the appropriate model lies with determining beforehand the drainage area scale, availability of water quality and hydrologic data, and availability of resources and personnel. When the appropriate model is selected, it can provide watershed managers with important guidance for targeting areas in need of protection and for predicting the magnitude and risks associated with pollutant loads.

Reference ID 126

Shamsi, U.M. (1996). "Storm-Water Management Implementation through Modeling and GIS." J. of Water Resources Planning & Management; 122(2), 114-127.

Keywords: Penn State Runoff Model, GIS, hydrologic model

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

This paper presents an integration of a lumped parameter hydrologic model (Penn State Runoff Model) with a planning level geographic information system (GIS) in implementing a watershed-wide storm-water management plan. The integration is used to estimate physical input parameters of the model. The model is used to simulate runoff hydrographs for various durations and frequencies and process the hydrographs to create peak flow presentation and release rate tables. These tables provide information to create a watershed release rate map that is a practical tool for implementing a storm-water management plan. It is demonstrated that the Penn State Runoff Model integration successfully implements the requirements of the Stormwater Management Act of Pennsylvania. An innovative GIS integration approach is presented that employs both the vector and the raster GIS formats to take advantage of the best features of each. Cost effectiveness of GIS integration is discussed and recommendations are made for future research. The proposed approach is illustrated for one small and one large watershed in Pennsylvania.

Reference ID 127

Lyon, S.W., Walter, M.T., Gerard-Marchant, P. and Steenhuis, T.S. (2004). "Using a topographic index to distribute variable source area runoff predicted with the SCS curve-number equation." Hydrol. Process. 18, 2757-2771.

Keywords: variable source area hydrology; curve number; topographic index; runoff prediction

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Because the traditional Soil Conservation Service curve-number (SCS-CN) approach continues to be used ubiquitously in water quality models, new application methods are needed that are consistent with variable source area (VSA) hydrological processes in the landscape. We developed and tested a distributed approach for applying the traditional SCS-CN equation to watersheds where VSA hydrology is a dominant process. Predicting the location of source areas is important for watershed planning because restricting potentially polluting activities from runoff source areas is fundamental to controlling non-point-source pollution. The method presented here used the traditional SCS-CN approach to predict runoff volume and spatial extent of saturated areas and a topographic index, like that used in TOPMODEL, to distribute runoff source areas through watersheds. The resulting distributed CN-VSA method was applied to two subwatersheds of the Delaware basin in the Catskill Mountains region of New York State and one watershed in south-eastern Australia to produce runoff-probability maps. Observed saturated area locations in the watersheds agreed with the distributed CN-VSA method. Results showed good agreement with those obtained from the previously validated soil moisture routing (SMR) model. When compared with the traditional SCS-CN method, the distributed CN-VSA method predicted a similar total volume of runoff, but vastly different locations of runoff generation. Thus, the distributed CN-VSA approach provides a physically based method that is simple enough to be incorporated into water quality models, and other tools that currently use the traditional SCS-CN method, while still adhering to the principles of VSA hydrology.

Reference ID 128

Hernandez, T., Nachabe, M., Ross, M., and Obeysekera, J. (2003)."Modeling Runoff from Variable Source in Humid, Shallow Water Table Environments." 39(1): 75-85.

Keywords: variable source areas, saturated zones, shallow water table, runoff prediction

☐ *Load Modeling* ☐ *BMP Modeling* ☒ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Variable Source Areas (VSAs) are zones with water saturated soils in forested wetlands fringing streams and creeks. Runoff from these areas is generated by saturation excess after a shallow water table rises and inundates the ground surface. In humid regions, like Florida and the Southeast, VSAs are believed to produce most of the runoff in shallow water table environments. Modeling the spatial extent and temporal fluctuation of a VSA is difficult because the formation of a VSA depends on a number of hydrological and morphological factors like rainfall intensity, soil texture, water table depth, and topographic attributes of the ter- rain. In this paper, we couple a digital elevation model with a two- dimensional variable saturation model to illustrate the formation of a VSA at the hillside scale. The topography derived from the digital elevation model forms the upper domain geometry for the two- dimensional finite element simulations of variable saturated flow. The objectives are: (1) to model the spatial and dynamic fluctuation of a VSA, and (2) to understand the roles of rainfall variability and terrain attributes on the formation of a VSA. Results show that hillsides with shallow water table depths, low saturated hydraulic conductivity, mild slopes, and concave slope curvature were more susceptible to runoff from a variable source. Runoff from a variable source showed little sensitivity to rainfall intensity. In general, landscapes with steep slopes generated a small VSA and a seepage face that vanished rapidly with time. In contrast, flat terrains are more amenable to VSA and retain ground surface inundation for longer periods of time.

Reference ID 129

Fitzpatrick, J., Imhoff, J., Burgess, E. and Brashear, R. (2001). "Water Quality Models: A survey and assessment." Prepared for the Water Environment Research Foundation, WERF Project 99-WSM-5

Keywords: water quality\\modeling\\reviews\\runoff model\\hydraulic model\\simulation models\\loading models\\receiving water models\\eutrophication\\toxics\\groundwater\\modeling systems\\screening\\planning

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

To assist in the model selection process, this research project evaluated the availability, assessment, and use of hydrodynamic, land-based runoff, and fate and transport models. Approximately 150 models or modeling systems were identified and evaluated in this study. To assist a perspective modeler in selecting the appropriate model(s) for a particular application, a computer-based Model Selection Tool was developed. It is included on the CD-ROM associated with this publication. The Model Selection Tool was developed using Visual Basic and includes a user-friendly interface, linked to an Access database containing HTML compiled model descriptions. The model descriptions also include hard-wired links to government, academic, and private sector websites for the model developers and, often downloadable versions of the model

Reference ID 130

Zou, R., Lung, W. and Guo, H. (2002). "Neural Network Embedded Monte Carlo Approach for Water Quality Modeling under Input Information Uncertainty." J. Comp. in Civ. Engrg., 16(2): 135-142

Keywords: Neural networks; Monte Carlo method; Water quality; Models

☒ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☒ *Nutrient Characterization*

Annotated Summary:

This paper proposes a neural network embedded Monte Carlo (NNMC) approach to account for uncertainty in water quality modeling. The framework of the proposed method has three major parts: a numerical water quality model, a neural network technique, and Monte Carlo simulation. The numerical model is used to generate desirable output for training and testing sets, and the neural network is used as a universal functional mapping tool to approximate the input-output response of the numerical model. The Monte Carlo simulation then uses the neural network to generate numerical realizations based on a probabilistic distribution of parameters, thus obtaining a probabilistic distribution of the simulated state variables. By embedding a neural network into the conventional Monte Carlo simulation, the proposed approach significantly improves upon the conventional method in computational efficiency. The proposed approach has been applied to uncertainty and risk analyses of a phosphorus model for Triadelphia Reservoir in Maryland. The results of this research show that the NNMC approach has potential for efficient uncertainty analysis of water quality modeling.

Reference ID 131

Qin, H., S.J. Burian, and F.G. Edwards (2004). "Development of a GIS-Based Stormwater Quality Management Planning Tool." Proc. World Water Congress 2004, July 1, Salt Lake City, Utah.

Keywords: GIS, load modeling, BMPs, construction site, runoff quality, USLE, simple method

☒ *Load Modeling* ☒ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

Increased federal regulation of stormwater runoff in recent years has concomitantly increased the interest of engineers, planners, and municipal officials towards the effective planning and design of stormwater management programs. Given the increased attention to stormwater management, the demand for technical tools to solve problems efficiently has arisen. To meet the demand for planning tools that can take advantage of spatial data, a Visual Basic for Applications tool for use within the ArcGIS 8.x geographic information system (GIS) software package has been created. The GIS tool offers a construction site erosion and sediment control module and a post-construction stormwater management module to aid the development of best management practice (BMP) plans. Within the GIS environment, BMPs can be placed on a site map and the automatic processing can be activated to determine the cost and pollutant removal performance of the BMP plan given spatial data describing site topography, land use/cover, and soil type. Site specific BMP performance and cost information can be input or a database of national cost and performance data can be used by default. BMP plans can be revised and the relative cost and performance of alternative plans determined and compared. The construction site erosion and sediment control module implements an erosion prediction algorithm based on the Revised Universal Soil Loss Equation (RUSLE). The post-construction stormwater management module implements Curve Number hydrology for long-term runoff volume prediction, as well as Event Mean Concentration associated with land use for pollutant load prediction. Monte Carlo water quality simulation and a BMP optimization routine are also being developed for later implementation.

Reference ID 132

Strecker, E., Urbonas, B., Quigley, M., Howell, J. and Hesse, T. (2002). "Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements." Prepared for the USEPA, EPA-821-B-02-001

Keywords: BMP\\monitoring\\performance\\database\\stormwater\\manuals\\

☐ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

This guidance has been developed by integrating experience gleaned from field monitoring activities conducted by members of ASCE's Urban Water Resource Research Council and through the development of the ASCE/EPA National Stormwater Best Management Practices Database. The manual is intended to help achieve stormwater BMP monitoring project goals through the collection of more useful and representative rainfall, flow, and water quality information. Many of the recommended protocols (particularly those for reporting monitoring, watershed, and design information) are directly related to requirements of the National Stormwater Best Management Practices Database. This manual is intended to improve the state of the practice by providing a recommended set of protocols and standards for collecting, storing, analyzing, and reporting BMP monitoring data that will lead to better understanding of the function, efficiency, and design of urban stormwater BMPs. This manual provides insight into and guidance for strategies, approaches, and techniques that are appropriate and useful for monitoring BMPs.

Reference ID 133

Lenhart, J.H. (2004). "Methods of Sizing Water Quality Facilities - A Comparison of Different Design Approaches."

Keywords: BMP design, BMP sizing, TSS as pollutant surrogate

☐ *Load Modeling* ☐ *BMP Modeling* ☐ *Hydrologic Modeling Only*
☐ *Sediment Characterization* ☐ *Nutrient Characterization*

Annotated Summary:

There are two basic design approaches for facility sizing: volume-based design and flow-based design. Ponds, for example, are sized on the volume of water they need to hold, which is usually a multiplier of the regulated treatment volume. Peak-flow-based BMPs, such as flow-through swales, are sized based on calculation of a peak flow resulting from a design storm, unit hydrograph, and rainfall/runoff model such as the Santa Barbara Urban Hydrograph.

There are many variants and hybrids of these two approaches. A sand filter might be sized on a volume basis but can be given a sizing credit for the volume of water treated while it is filling. The average annual load method correlates the efficiency of a BMP with a flow distribution calculated from a rainfall intensity distribution from hydrologic data. Other methods include mass-based design and effluent-limit-based design. This article provides brief descriptions of each method, with examples and pros and cons.

Reference ID 134

USEPA (1983). Final Report of the Nationwide Urban Runoff Program. Water Planning Division, Washington, DC.,

Keywords: runoff, water pollution, urban areas, hydrology, stream flow, rainfall, snowmelt, land use, sediment transport, water quality management, watersheds, storm water runoff, urban hydrology

Load Modeling **BMP Modeling** **Hydrologic Modeling Only**

Sediment Characterization **Nutrient Characterization**

Annotated Summary:

This document summarizes the Nationwide Urban Runoff Program.

Reference ID 135

E.D. Driscoll, P.E. Shelly, and E.W. Strecker (1990). "Pollutant loadings and impacts from highway stormwater runoff -- Volume III: Analytical Investigation and Research Report." Prepared for the Federal Highway Administration, FHWA/RD-

Keywords: highway runoff, stormwater monitoring, water quality,

Load Modeling **BMP Modeling** **Hydrologic Modeling Only**

Sediment Characterization **Nutrient Characterization**

Annotated Summary:

This is one of four final documents of an investigation dealing with the characterization of stormwater runoff pollutant loads from highways and the prediction of water quality impacts they cause. Study results are based on monitoring data from 993 individual storm events at 31 highway runoff sites in 11 States. Impact prediction is based on a methodology previously developed and applied to urban runoff and adapted for highway runoff applications. The document describes the procedures used to assemble and analyze the data base and reports the results of these analyses. Included in the document are statistical summaries of the data base, along with a description of procedures to use to predict pollutant discharges from highway sites and the impacts that they will cause to receiving waters.

Reference ID 136

Schueler, T.R. (1987). Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Washington Metro. Water Res. Planning Board.

Keywords: BMP design, stormwater management, BMP performance, stormwater treatment

Load Modeling **BMP Modeling** **Hydrologic Modeling Only**

Sediment Characterization **Nutrient Characterization**

Annotated Summary:

This report presents a semi-quantitative comparison of BMP pollutant removal rates based on inferences from field studies, laboratory experiments, modeling analysis, and theoretical considerations. The BMPs included extended-detention (dry) ponds, wet ponds, infiltrtion trenches, infiltration basins, porous pavement, water-quality inlets, filter strips, and grassed swales. Planning considerations, recommended sizing and design features of BMPs are reported. Provides detailed guidance for engineers and planners on the design and planning of urban BMP for pollutant removal and stream habitat protection. Manual provides detailed guidance for engineers and siteplanners on how to plan and design urban best management practices (BMPS) to remove pollutants and protect stream habitat. Describes water quality and habitat impacts in streams that result form uncontrolled watershed developement. Contains a simple method for estimating pollutant export from development sites. Presents a series of tools to assist the site designer in selecting the best BMP option for a site. Provides detailed design guidance on seven major urban BMP practices in use in the Washington Metropolitan Area: extended detention ponds, wet ponds, infiltration basins and trenches, porous pavement, water quality inlets and vegetative practices. Each BMP is reviewed from the standpoint of stormwater management benefits, pollutant removal, physical feasibility, costs, maintenance requirements, and impacts to the environment and adjacent communities. A list of recommended design standards that enhance BMP performance is also presented.

Wednesday, April 13, 2005

Methodology to Estimate Pollutant Load Reductions

Appendix F – Comments and Responses

Final Report

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Contract DACW05-02-D-0001-0007-01
April 21, 2006

Table of Contents

List of Tables

F.1 Summary of Process

Comments regarding the developed methodology, as well as the Pollutant Load Reduction Estimator – Spreadsheet for Tahoe Storm Water (PLRE-STS) were solicited using the following three forums: 1) stakeholder presentations, 2) follow-up interviews, and 3) requests for written comments.

Stakeholder presentations were held on February 8th, 2006 at TRPA and on March 14th, 2006 at the North Shore Conference Center. The February 8th presentation was held for Tahoe agency staff. The March 14th presentation was an open invite. Both presentations were similar in content, presenting an overview of the project in the morning and the details of the PLRE in the afternoon.

Follow-up interviews were conducted after both the February 8th and March 14th stakeholder presentations. Tahoe agency staff were interviewed after the February 8th meeting. Selection of interview participants was based upon attendance at the presentations and structured to provide a cross-section of responses from Tahoe Basin agencies given the resources allocated to the task. The March 14th stakeholder meeting was primarily attended by consultants. Various consulting firms were interviewed after the March 14th meeting. Comments and responses from the follow-up interviews are presented in Section F.2.

The March 14th presentation announcement, sent out via email on March 2nd, 2006, included directions for downloading the draft report and draft appendices. A reminder email was sent to the same distribution list on March 29, 2006 notifying stakeholder that the materials were still available for download and review, but that the commenting period would close on April 5, 2006. Written comments received by April 5th, 2006 are presented in Section F.3 with responses.

F.2 Follow-Up Interviews

Comments from the follow-up interviews were synthesized into common themes and are included below. Interview comments associated to agency staff and consultants are presented separately in Section F.2.1 and F.2.2. Table F-1 displays the interview questionnaire used for all interviews.

Table F-1. Follow-Up Interview Questionnaire

1	Is the general approach used in developing the methodology reasonably clear to you? If not, what parts need clarification?
2	Do you have questions, comments, or suggestions on the approach (major changes in emphasis, elements, or overall approach)?
3	Recognizing that there are limitations on available data at this time, do you have suggestions on the methods used in the PLRE-STS to estimate pollutant loads? Please consider methods in 3 categories in your response - Hydrology, Load Generation, Load Reduction.
4	Do you have data or procedures that you think could improve the computations?
5	What applications do you foresee for the methodology?
6	How could it be improved to facilitate these applications?
7	What do you think are the main limitations and drawbacks?

8	What are the highest priority limitations to work on?
9	What do you foresee as the potential future intersection between TMDL programs and policy and application of the methodology? What potential problems or benefits do you foresee? What needs to be clarified in this regard?

F.2.1 Agency Interviews

The following section summarizes comments received from interviews with Lake Tahoe agencies. The interviews were conducted to solicit stakeholder feedback from the pollutant load reduction methodology presentation held on February 8th, 2006 for Lake Tahoe agency staff. Interviews summarized in this document were conducted on February 17th, February 21st, and February 24th. Table 1 lists the agencies interviewed along with the personnel interviewed at each agency. A total of eight interviews were conducted based on available resources.

Table F-2. Agency Interview Participants

Agency	**Date Interviewed**	**Personnel Interviewed**
TRPA	February 17th	Tim Hagan
		Jon-Paul Harries
		Brendan Ferry
		Rita Whitney
United States Forest Service	February 17th	Catherine Schoen
		Jerry Harper
El Dorado County	February 17th	Steve Kooyman
Nevada Tahoe Conservation District	February 21st	Jason Drew
		Chad Praul
California Tahoe Conservancy	February 21st	Steve Goldman
		Zach Hymanson
		Theresa Loupe
		Russ Wigart
		Scott Cecchi
		Scott Carroll
Lahontan Regional Water Quality Control Board/NDEP	February 21st	Doug Smith
		Bob Larsen
		Erich Simon
		Jason Kuchnicki
Nevada Department of Transportation	February 21st	Theresa Jones
		Vanessa Gallo
Placer County	February 24th	Peter Kraatz
		David Vaccarello

The interview questionnaire developed was used to facilitate discussion, but in general the questionnaire was found too specific for most interviewees given their limited exposure to the methodology. In general, the interviews evolved into a general discussion of the methodology and PLRE-STS. Comments from the eight interviews are summarized below based on the topics frequently discussed.

1. Clarify TMDL Implications of Methodology and PLRE-STS

In general, interviewees were unclear with the expected application of the methodology and how it would fit into the TMDL program, including the linkage to the watershed model. Presentations subsequent to interviews should emphasize the implications of the methodology and the meaning of the current PLRE-STS. Most respondents asked to see a timeline of development emphasizing where the PLRE-STS fits along the timeline. Certain respondents indicated a need for a memorandum identifying the ramifications that the PLRE-STS may have on policy.

Response: The subsequent presentation to Lake Tahoe stakeholders held on March 14th included an expanding session focusing on future applications of a pollutant load reduction methodology within the TMDL Program. The next steps foreseen by the project advisory committee was developed and included in Section 9 of the final report. During the development of the Integrated Water Quality Management Strategy, Lahontan will be exploring the application and development of various approaches to estimate load reduction from each source category. Potential policy implications will be evaluated at that time.

2. Relative Accuracy and Sensitivity of the PLRE-STS

In general, most interview respondents were uncomfortable with the methodology without understanding the relative accuracy of the PLRE-STS and the associated sensitivity. While all respondents acknowledged that absolute accuracy was neither needed nor expected, they generally felt that addressing inaccuracy and sensitivity was important to inform and manage the TAC process. Several ideas for addressing inaccuracy and sensitivity were mentioned:

- Develop clear parameter estimation procedures.
- Perform sensitivity analysis from single parameter adjustment and evaluation.
- Develop a user's manual that discusses sensitivity of parameters when changed from default values.
- Don't allow adjustment of default values at the TAC level.
- Provide a range of pollutant loading using statistical analysis of hydrology output.
- Identify a central entity responsible for updating and refining the methodology.

Response: Initial testing and parameter verification of the PLRE-STS is identified as a necessary step before distribution of a beta version of the PLRE-STS. It is anticipated that these issues will be evaluated during this process.

3. Concerns Over Potential Bias

Respondents want the developed methodology to minimize bias and give the proper credit towards designs that are encouraged. Most recognized that in the absence of adequate supporting data this is an extremely challenging goal. A concern repeatedly mentioned was that experienced users of the PLRE-STS would likely be able to shape the selection of an alternative towards a desired outcome.

Response: Developing an objective methodology is a recognized goal. Testing will be required to identify and correct any bias.

4. Misapplication and Over Reliance of the Tool

A repeatedly identified topic was the potential misuse of the methodology and PLRE-STS, particularly at the TAC level. Managing expectations of the PLRE-STS was commonly discussed. Interviewees stressed a clear message is needed, which explains and emphasizes that the tool is only one application to assist in informed decision making. Additional concerns and suggestions were as follows:

- Project delivery needs to be realistic and based on collective experience of the TAC. The PLRE-STS will not consider other elements of the project delivery process such as feasible implementation, sustainability, or cost.
- Alternative analysis could lengthen with the tool. An endless loop of modification and optimization is possible.
- Make it easy compare multiple simulations to assist the process is essential.
- Provide reporting of parameters that have been changed from default values.

Response: The appropriate applications of the methodology will need to be defined with guidance for application developed during the initial testing and parameter verification process of the PLRE-STS.

5. Represent Private BMP Implementation

Most interviewees discussed the need to track and credit private BMP implementation. Interviewees acknowledged a lack of private BMP effectiveness data, particularly when considering long-term effectiveness, which is reliant on private BMP maintenance.

Response: Methods to represent the effects of private BMP implementation were further developed and included in the report. The current methods provide limited applicability and resolution for private BMP implementation. Development of more refined methods is identified as a next step.

6. Source Accounting Subjective

While interviewees were aware that source control effectiveness data is lacking, they were concerned with the subjectivity of the methods proposed. However, most respondents found the logic behind the methods to be reasonable. Quite a few interviewees were interested in the details of the USLE method for estimation of disturbed area erosion and inquired about the application of WEPP. The need for water quality data to quantitatively define source control benefits was repeatedly recognized.

Response: Development of more refined methods is identified as a next step.

<u>7. Eager to Apply Pilot Applications and Test</u>
Agencies and interviewees were eager to apply the methodology. Respondents mentioned testing the methodology under varying project conditions and locations to evaluate how results may vary. Respondents mentioned that pilot applications should proceed in a logical format with results compiled and summarized by one entity. A robust testing program with a set protocol for feedback and reporting of issues was discussed.

Response: Agreed; key refinements, improvements, and testing are needed before any release of the PLRE-STS. After refinements have been completed, release of a beta version of the PLRE-STS for controlled pilot testing is proposed.

<u>8. Lumped Parameter and Continuous Modeling Implications and Emphasis</u>
A large portion of the questions asked by interviewees were due to misunderstandings or unfamiliarity with lumped parameter and continuous modeling assumptions. These two concepts should be emphasized more in the presentation and report. Respondents were concerned that due to the lumped-parameter assumption, the proximity of a source to receiving water would not be weighted properly.

Response: The final report better emphasizes and explains these concepts.

<u>9. Static Parameter Concerns</u>
Some respondents mentioned the difficulty that will be encountered when estimating static parameters over long-term simulations (e.g. infiltration rates and BMP effectiveness). Seasonal changes in high groundwater were mentioned as an inter-annual consideration.

Response: This is a current limitation of existing data and the methodology. The feasibility and need for time variable or seasonal analysis should be incorporated into testing and development.

F.2.2 Consultant Interviews

The following section summarizes comments received from interviews with Lake Tahoe consulting firms. The interviews were conducted to solicit stakeholder feedback from the pollutant load reduction methodology presentation held on March 14th, 2006. Table F.3 lists the firms interviewed along with the personnel interviewed at each firm. Selection of interview participants was based upon attendance at the March 14th presentation. A total of five interviews were conducted based on responses to requests for interviews.

Table F-3. Consultant Interview Participants

Firm	Date Interviewed	Personnel Interviewed
IERS	March 22nd	Michael Hogan
Kennedy Jenks	March 23rd	Chris Conway
		John Buzzone
c2me Engineering	March 23rd	Chris Twomey
Entrix	March 23rd	Steve Peck
CDM	March 23rd	Stefan Schuster

The interview questionnaire developed was used to facilitate discussion, but in general the questionnaire was found too specific for most interviewees given their limited exposure to the methodology. In general, the interviews evolved into a general discussion of the methodology and PLRE-STS. Comments from the eight interviews are summarized below based on the topics frequently discussed.

1. Functionality of the PLRE-STS

The consultants interviewed were relatively familiar with the alternatives analysis process and mentioned a desire for a tool with a high level of functionality. Interviewees mentioned that a robust and flexible tool would greatly simplify the complexity and time allocated for the alternatives evaluation process. General requests included the need for multiple catchments, simulation of storm water treatment anywhere within a catchment, more tools to track changes, and the ability to make global changes.

Response: The development of the PLRE-STS was not originally anticipated in the scope of work. The current version of the PLRE-STS is a prototype constructed to evaluate and illustrate the developed methodologies in a logical framework. The next steps identified in the report are intended to address this need.

2. Relative Accuracy and Sensitivity of PLRE-STS

Interviewees were interested in the relative accuracy of the PLRE-STS and the associated sensitivity for comparison of alternatives. In general, consultants recognized a need to address the relative accuracy of their selected method for evaluating alternatives in order to inform and mange the TAC process.

Response: Evaluating the relative accuracy and sensitivity of the PLRE-STS is identified as a necessary step before distribution of a beta version. See section 9.2 of the report for a discussion regarding accuracy and application of computational results.

3. Assumptions for land use EMCs and BMP effectiveness

Interviewees recognized the land use EMCs and BMP effectiveness assumptions used in the methodology have a profound affect on pollutant loading. Interviews desired review of the assumptions and methods used to develop land use EMC data and BMP effluent concentrations in the methodology.

Response: A detailed description of how the land use categories and EMCs were developed for the TMDL program will be included in the Draft Technical TMDL document to be released independently from this work in the summer of 2006.

The methodology currently uses median BMP effluent concentrations from data in the International BMP Database (www.bmpdatabase.org) as default values. While it is recognized that the performance data contained in the BMP database may differ from BMPs in the Tahoe Basin (Strecker et al. 2005). Tahoe-specific data are currently too limited to develop statistically robust performance estimates for many BMP types.

4. Define and use consistent terminology for source control
The terminology for source control in the report is inconsistent and not adequately defined. Revise the report to specify what is meant by source control.

Response: The project team revised the report to use a consistent terminology for source control, including definitions explaining what is meant by source control. Source controls are described in the report using two categories: pollutant source controls and hydrologic source controls. Pollutant source controls limit the supply of pollutants on the watershed and therefore limit the potential for certain pollutants to be mobilized and transported during a storm event. Hydrologic source controls limit runoff by retaining or providing for the natural processes of interception, infiltration, and evapotranspiration.

F.3 Written Comments on Draft Report

Written comments received by April 5th, 2006 are presented below with responses. Comments and responses are organized into common categories. Editorial comments and requests for clarification were addressed directly in the final report and are not discussed in this section. Additionally, some comments have been slightly modified to maintain the anonymity of the commenter. Conversely, some comments were purposely left in their original context to identify the organization commenting. This was only done when the project team felt the commenting organization wished to be identified (e.g. Caltrans, NRCS, etc.).

F.3.1 Future Development and Implementation of the Methodology

Comment #1:
It is extremely important to create a tool basket of PLR field BMPs that will handle the anticipated need. It would be beneficial to have the PLR regulators work with implementers to produce a Tahoe Basin BMP manual for the PLR for use by all implementers, which would include private developers, and help train young engineers who are assigned tasks in the Basin.

Response: Agreed; the final report describes the need for a Tahoe Basin BMP design manual and guidance.

Comment #2
I'm sure the scientific community can create PLR program criteria. However, I am focused on how to implement, to construct facilities to handle loads of sediment and chemicals for the prevention of the materials from entering water bodies. When will that occur?

Response: The design of water quality improvement projects is continuing in the Tahoe Basin based on the training and judgment of project designers. The purpose of the methodology is to provide quantitative means to assess the effectiveness of these design alternatives, and to create a system where the cumulative benefits of projects can be tracked and credited towards achieving an overall goal for protection of Lake Tahoe's clarity. As noted above, the report supports the concept of developing the quantitative assessment tools in combination with BMP design criteria so that design and implementation of projects becomes more straightforward and the results more certain.

Comment #3
It seems to me that your model development and validation may benefit from the large amount of existing data, if it were in a more useable and standardized form. There is an extensive amount of analytical and hydrologic raw data that if compiled and evaluated in a standardized manner, could be much more useful. I would like to possibly discuss these options with the project team, in addition to potential standardization and data collection efforts that we are conducting currently.

Response: Agreed; the initial testing and verification work will use as much existing data as possible, and this effort would be facilitated by standardized compilation and evaluation of monitoring data.

Comment #4
In processing many storm damage related repairs, I know and understand that the geotechnical processes are a major factor in load creation. I would think that the PLR group should also work with geotechnical experts to identify friable material sources in watersheds. Work that I have produced in the coastal waters of CA has shown that the type of repair, for failing slopes, etc. is a major source reduction activity. Hopefully that is being taken into account.

Response: The pollutant loading described would be considered a specific source in the methodology. Although further development of the computational methods is needed, we agree that these are significant sources of pollutants and need to be accounted for in the application of the methodology.

Comment #5
Calibration of BMP modeling using monitoring data is one of the most important tasks and should be a high priority. A real watershed with data collected from it, is necessary to give a reality check to the model.

Response: The PLRE-STS is a prototype computational tool used to illustrate and evaluate the conceptual methodology. In the context of the report, "prototype" means that a relatively complete computational tool is ready for initial testing and further development. The report recommends initial testing and verification of results against Tahoe monitoring data prior to broader application.

Comment #6
Should mention that the "...entire area is routed to a single discharge point via overland flow rather than concentrated flow." earlier in the report, and discuss the implications of this (i.e. smaller flow rates than naturally occur).

Response: Statement as written was misleading. Revised report to read: "The current methodology only allows for the simulation of one catchment with the option to route runoff from impervious/pervious areas either directly to the storm drain (or BMP treatment train) or to a primary pervious conveyance system." Flow rates may be adjusted by modifying assumptions for connectivity to the outlet of the catchment.

Comment #7
Consider adding another item for the guidance manual: provide more detail about default conditions.

> *Response: A recommended next step has been added to Section 9 of the report: "Provide documentation describing how default values were developed, including associated assumptions."*

Comment #8
The report identifies the need of a "brief user's manual...". The manual should include all references for the methods and procedures used in determining pollutant loads.

> *Response: See response to Comment #7 above.*

Comment #9
Creation of a User Friendly Manual: the manual should consider that the user will be entering in their own data sets. Therefore the user manual should cover disclaimers on how the model works, what datasets are being accessed etc. For example – There are also datasets from 16 sites around the basin – per the TRG study (2001-?). How good is that data. What does EMC mean – did they capture the whole storm, the rising limb, the peak, or miss it completely. Does it really compare that well to what others have done nation-wide. And, I have serious concern if a non-certified lab was used – how will these numbers hold up in court. What lab method was used – a journal article (?), a standard method, an EPA method, etc. What was reported – the detection limit (background) or the reporting limit.

> *Response: A user's manual is a recommended next step including documentation of methods and assumptions as discussed in the response to Comment #7 above. However, caution is needed in application of user specified data sets. Short-term, project specific data may give undue weight to normal variations in water quality in particular storm events, seasons, temporary land use conditions, or other spatial or temporal variance, and not represent the long-term average. Justification for modifying default values for individual projects should be carefully considered, although project specific data will be useful in the long-term to make regional refinements.*

> *Regarding EMC data, assumptions, and techniques - a detailed description of how the land use categories and EMCs were developed for the TMDL program will be included in the Draft Technical TMDL document to be released independently from this work in the summer of 2006.*

Comment #10
From NRCS - the SWMM uses soils information as an input, NRCS is moving toward releasing the updated Soils Survey for the LTB, and we should maintain contact with the project team as it's released, and perhaps discuss the new data and the new tools for using the survey after release.

Response: Added a recommended improvement to Section 9 – "incorporate updated Soil Survey data and tools when available."

Comment #11
We strongly support the use of monitoring to ensure that the design parameters, as well as the modeling techniques, are derived from or adjusted based on actual conditions and performance. We suggest an additional recommendation as new item 7, as a follow-up to the statement on Page 14.

Recommendation: The Lahontan Board should review the effluent discharge standards to ensure they are focused on the pollutants of concern, are achievable using reasonably available BMP's, and can be incorporated into the BMP design standards.

Response: It is the intent of both the PATHWAY Process and the Integrated Water Quality Management Strategy to evaluate water quality standards, control measures and management strategies. Included in these evaluations is the development of processes to evaluate achievable load reductions from all source categories.

Comment #12
Caltrans (and others) has already produced BMP design manuals as well as water quality performance data. This existing information should be reviewed before recommending a new BMP design manual and hydrologic design manual.

Response: The project team reviewed the Storm Water Quality Handbook - Project Planning and Design Guide (Caltrans 2002). This document is now referenced in the report and recommendations for development and adoption of a Tahoe specific BMP Design Manual now refer to the Caltrans document as an example of available guidance and a potential framework.

Comment #13
All of the BMPs should be presented in a BMP "toolbox" similar to the manual that Caltrans put out. However this manual would include more "un-conventional BMPs".

Response: Agree with the need for a BMP Design Manual, and this is mentioned in the report. Also agree with the need for an expanded manual with BMPs not included in the Caltrans handbook discussed in Comment #12 above. Consideration should also be given to expanded design criteria for more conventional BMPs so that key design parameters (hydraulic loading, vegetative conditions, soils, etc.) can be linked to performance.

F.3.2 Target Applications of the Methodology

Comment #1
This report addresses the urban setting. What is being proposed for the rural or non-urban environment?

Response: Section 6.5 of the final report was added to address the appropriate applications of the methodology developed for this project. Phase II of the TMDL will begin to address all significant pollutant sources (e.g., upland erosion, stream erosion, atmospheric deposition) and similarly track pollutant reductions occurring in these source categories. However, the development of methodologies from all source categories will take time and will need to be developed in such a way as to allow for continuous improvement and adaptation. See response to comment #11 in Section F.3.1.

<u>Comment #2</u>
The executive summary states that "The approach was to develop a methodology applicable to catchments on the order of 5 to 100 acres in size." So what is proposed to handle watersheds outside this range?

Response: The PLRE-STS was developed to evaluate pollutant load reductions for catchments on the order of 5 to 100 acres in size, recognizing that this is a common size for water quality improvement projects in the basin and involves considerable complexity. The conceptual methodology offers promise for adaptation to address both smaller and larger areas. However, this would require different computational tools to address differences in important processes for generation, transport, and routing of pollutants at these scales. Currently, the LSPC watershed model addresses larger scale pollutant loading estimates. The project team is not aware of a similar methodology for smaller scale pollutant loading estimates. See response to Comment #1 and Section 6.5 of the report.

<u>Comment #3</u>
Perhaps it would be valuable when you provide some of these products to specifically note that they do or don't apply to the Single Family Residential (SFR) scale. For example, on the Storm Water Treatment methodology, I don't see your treatment BMP spreadsheet applying to SFR, but we do use many of those practices. It would be very helpful in heading off confusion if you clearly define where these spreadsheets can and can't be used.

Response: See responses to Comment #1 and #2; and Section 6.5 of the report.

<u>Comment #4</u>
Why aren't upland and stream erosion accounted for in this methodology as they are in the watershed model? May want to include an explanation in this section of the report.

Response: The PAC decided early in the project to focus on the urban storm water sources. This is partly due to the desire for increased resolution compared to the LSPC model for these sources. The LSPC model is better able to compute upland and stream channel erosion at a larger scale. The methodology does account for drainage system stabilization at the project scale.

<u>Comment #5</u>
It is not clear whether the modeling effort will adequately focus on pollutant load reductions from hydromodification controls (i.e., flow volume and peak flow reductions resulting in less

stream scouring and erosion). ‘In-Stream Controls,’ including hydromodification controls, are identified in the table on page 44. It is not clear, however, to what extent the modeling effort will address these effects.

Response: The table showing “In-stream controls” has been modified to avoid confusion. To the extent that hydromodification generates larger urban runoff volumes to drainage system outlets and treatment BMPs, the methodology accounts for these effects. The report recommends additional development of tools to use the flow-duration information generated by the methodology to assess downstream impacts of hydro-modification, such as increased stream erosion. Stream channel erosion is a major source category that will be evaluated during the development of the Integrated Water Quality Management System.

Comment #6

There appears to be a skewed focus on urban areas in the modeling effort. The urbanized areas make up only a small fraction of the total drainage to Lake Tahoe, so these other areas need to be evaluated as well.

Response: See response to Comment #1 and #4, and Section 6.5 of the report.

Comment #7

The model being produced by Northwest Hydraulic Consultants (NHC) can calculate runoff amounts and pollution level reduction for a single large watershed, such as a subdivision. However, most Caltrans property in the Tahoe Basin is in the form of linear highways that make up approximately 500 small catchments. Most of these catchments have varying properties, such as curb types, median widths, number of lanes, and BMP types. This model is not appropriate for Caltrans linear systems and would be extremely cumbersome to use for such a large number and wide variety of catchments. Caltrans has already started work on a model that uses methodologies that are similar to the ones in the NHC model, but can calculate runoff loads at all of the catchments in the Tahoe Basin at the same time.

Response: The current PLRE-STS only allows for single catchment simulation. Agree that application to linear projects as described in the comment would be technically challenging. Additional development of the PLRE-STS, as identified in recommended improvements in Section 9 of the report, could assist the analysis described in the comment.

Comment #8

On page 6 of the executive in the last paragraph, there is reference to major centralized treatment BMPs. An example of what a major facility needs to be presented so that all reading this document have an idea as to what this setup might be. Linear projects would not typically include centralized treatment of stormwater runoff.

Response: Examples are provided in final report and include: wet and dry basins, wetland treatments, bioswales, infiltration galleries, and filtration systems. See response to Comment #4 above regarding linear projects.

F.3.3 Hydrology, including Event vs. Continuous Simulation

Comment #1

The SQWIC group has developed Hydrologic Guidelines. These guidelines are specific to Tahoe and should be incorporated into the Pollutant Load Methodology. These guidelines also address Tahoe specific rain on snow event hydrology which should supersede and or supplement the methods used in SWMM.

> *Response: The selected approach uses a continuous simulation of hydrology to evaluate pollutant loading. This approach is preferred because it takes into account the sequence of storms, wet vs. dry years, and the effects of infiltration and evapotranspiration on the water balance. The advantage of continuous simulation from a water quality perspective is that actual or synthetic meteorological data can be used directly without statistical interpretation, and that variations in runoff due to changing antecedent or watershed conditions can be inherently accounted for in the simulation. However, this methodology should not be used as design guidance for facilities that require flood management analysis (e.g., storm drain sizing). Facilities of this nature should still be designed to meet flood management criteria which typically requires an analysis of event-based methods using precipitation depth-duration-frequency for a particular design event (e.g., 100-year, 24-hour event; 20-year 1-hour event, etc.). See Section 5 of the report for more discussion regarding the selected approach using continuous simulation of hydrology.*

Comment #2

Use of state-of-the-art techniques, in many instances, is hindered due to site constraints.

> *Response: Agreed*

Comment #3

Runoff can be overestimated without hydraulic routing.

> *Response: The current PLRE-STS computational routines do not include hydraulic routing. This was a simplifying assumption necessary to accomplish the scope of work within the allocated resources. Runoff might be overestimated, but simplified sensitivity testing indicated that this is not as significant a factoring the results as other input parameters. This may partly be due to larger emphasis on runoff volumes in this methodology rather than peak flow computations.*

Comment #4

In a number of places, the document discusses the preference of continuous simulation modeling for hydrology and then using EMCs for pollutant load generation. Is there a disconnect here with linking hydrology with loads using two different methodologies?

> *Response: The project team evaluated more process based approaches to water quality but felt that at the desired project scale, a process-based approach to water quality would likely lead to a very high level of complexity to model and require an extensive*

amount of input data and assumptions. In the future, a more process-based approach may be feasible, and the hydrologic simulation would support this modification. See Sections 4.3 and 5 of the report for a detailed discussion.

<u>Comment #5</u>
Why would you use MM5 for the hydrology component when we are currently trying to establish consistent hydrology modeling standards using NOAA data? I think everyone agrees that both MM5 and NOAA require calibration work, and if this work is done simultaneously by the same consultant, maybe the concern goes away; that is, if both MM5 and NOAA data are calibrated off of similar precipitation data, then maybe we all feel more comfortable that there is a better connection between the two data sets (even though they are used differently with respect to application in modeling - statistical vs. actual historical).

Response: Agree that consistency between the two data sets is desirable. However, as noted in the comment, the current applications are different, and differences between statistical parameters will not necessarily result in any conflict between applications. See response to Comment #1 regarding continuous vs. event based hydrologic representation.

<u>Comment #6</u>
Need to provide more information about the limitations and inaccuracies of the MM5 dataset. Also should specify how temperature was used to estimate snowfall and snowmelt.

Response: An independent analysis from this work found that the MM5 precipitation prediction is consistently lower than the observed SNOTEL reported precipitation, although relative spatial variation approached observed trends in the Basin. Overall, the MM5 data tended to under-predict precipitation between October and May. The TMDL program recognizes MM5 refinement and recalibration as a top priority for future funding.

The report references the SWMM manual for snow calculations.

<u>Comment #7</u>
If particle settling is the only treatment proposed for removing fines, consideration needs to be given to the large volume that will be need to be detained as well as the detention time. What happens when storms occur on a 2-3 day cycle such as what we have been seeing in the month of March? Will all the runoff following the first runoff event be bypassed since the first event is still "being" treated?

Response: Efficiency of removal of fines is a function of storage volume, detention time, and hydrology. The two SWMM blocks used in the methodology (Runoff and Storage/Treatment) account for these aspects of BMP Hydrology for discrete particle settling used to estimate fine sediment removal. The advantage of using continuous simulations for hydrology is that typical storm cycles are taken into account directly.

F.3.4 Pollutant Load Generation and Pollutant Source Controls

<u>Comment #1</u>
It should be noted that stabilization of road shoulders through paving and curb and gutter "improvements" (recommended in areas where vegetation establishment is impractical) can be detrimental, especially in areas where concentrated flows can not be adequately dissipated due to steep slopes. In some instances, allowing runoff to sheet flow from these "high priority road shoulders" is the best practice.

> *Response: Agreed; guidance and technical methods for evaluating road shoulder stabilization needs improvement in the methodology. This is noted as a recommended improvement in Section 9 of the report.*

<u>Comment #2</u>
Why was achievable effluent quality selected as a preferred approach over estimated percent approval for storm water treatment?

> *Response: Although the achievable effluent quality approach has limitations, the project team felt that achievable effluent quality provides a better representation of pollutant load removal, particularly for BMP treatment trains. More sophisticated techniques were not considered justified based on available information and level of complexity in the computations. Percent removal methods tend to overestimate removal when influent concentrations are low. See Section 7.3.3. of the report.*

<u>Comment #3</u>
BMP maximum achievable results are also specified in Table 6.1 on pages 53-54. It would appear that using average performance capability would provide more useful results. We also question the use of BMP effluent quality rather than percent removal. As shown in Table 7.6, page 78, effluent quality is extremely variable. This variation is at least partially attributable to influent quality.

> *Response: See response to Comment #2 above.*

<u>Comment #4</u>
TSS vs. SSC and confusion over Suspended Sediment is obvious – and is present throughout the model. If TSS is represented as Suspended Sediment, there is a blatant error, and also the value for load would be bias high. TSS = Total Suspended SOLIDS. SSC = Suspended Sediment Concentration.

> *Response: The methodology uses TSS to maintain consistency with TMDL EMC data and the watershed model. The Draft Technical TMDL document to be released independently from this work in the summer of 2006 is the appropriate document to address TSS vs. SSC.*

Comment #5

Won't increasing the impervious area flowing to pervious areas lead to increased surface runoff during large storm events? Not necessarily representative of actual effects of private BMP implementation. This limitation of Method 1 should be mentioned in this section of the report.

> *Response: Agree that this scenario could potentially occur with the current approach of Method 1 for private BMP representation, the current structure of the report focuses on limitations in Section 8.*

Comment #6

Basing the annual nutrient loading rates on a ratio of TSS leads to significant inaccuracies (to my knowledge, there is no reliable ratio of nutrients to TSS from LT monitoring data), this issue should be addressed.

> *Response: Agree; this is recognized as a limitation of the specific source accounting technique in need of improvement.*

Comment #7

From NRCS, in regard to Single-family residential (SFR) scale BMP's: I fully understand that residential scale properties are not the target of your Methodology. SFR scale properties are not the target of any particular methodology, therefore we tend to use whatever is out there and try and adapt it to this program

- According to the latest numbers, about 2,890 SFR properties have installed BMP's
- That leaves an estimated 27,723 properties left to install BMP's
- If we consider an average installation from this point in time to cost $5,000 then that will be an investment (private) totaling $138,615,000 when the remaining properties comply
- On the last page item #8 is to "refine methods for accounting for private property BMP implementation". Perhaps from our biased viewpoint we would recommend moving that up in the list, considering the total cost of implementation this portion of EIP 16.

> *Response: Agree with the significance of private contribution to the EIP. The project team has decided not to specifically prioritize technical improvement by task in the final report, including the need to improve representation of private BMP implementation in the methodology. The recommended improvements in Section 9 of the final report are made for the long-term, recognizing that near-term improvements will be constrained by schedules, available funding, and data and methods that are developed outside the scope of the PLRE-STS.*

Comment #8

Is there a known application rate for sand on highways within the land-use category for highways? If so, only application rates that exceed this known rate should be accounted for as a specific source. If not, road sanding will definitely (not maybe) be accounted for twice when it is identified as a specific source.

> *Response: Further guidance and technical development of pollutant load generation and pollutant source control accounting techniques are a recommended improvement to the*

methodology. A user could potentially double-count certain pollutant sources in the current methodology.

Comment #9
Caltrans is in the process of preparing a report entitled: "Water Quality Impairment from Contaminants on Particles: Size-Dependent Composition in Roadway Runoff," which may be useful when it becomes available.

Response: Report noted for future review.

Comment #10
The characterization of the fine particle percentage for various land uses seems highly speculative. The report (Table 7.2) indicates that a very high percentage of the TSS is in the small size fraction, even for highway sites with very high TSS resulting from sanding and other factors (up to 63 percent). Data from Texas indicates the opposite is true (Karamalegos et al., 2005). The table below (*not included with the response to comments*) reports the percentage of SSC for various particle sizes. For the sample (5/8/2005) with the concentration closest to that assumed for highways in the Tahoe basin, only 11 percent of the particles had diameters of less than 75µm. This will make a huge difference in the estimated efficiency of facilities that depend on gravity separation for pollutant removal.

Response: Particle size distribution estimates are median values using data from 16 TMDL monitoring sites to characterize different land use types. A detailed description of how the land use categories and EMCs were developed for the TMDL program, including particle size distribution, will be included in the Draft Technical TMDL document to be released independently from this work in the summer of 2006.

Comment #11
Assigning TSS values for specific sources as gully erosion also seems highly uncertain. These sources can represent a substantial fraction of the total load, so assigning an arbitrary value can skew the results substantially.

Response: It is recognized that the gully erosion prediction method in the methodology is subjective and needs improvement and additional guidance - this is identified in the report as a recommended improvement. However, the report does not suggest that "arbitrary values" for gully erosion should be allowed. All assumptions for defining a specific source of pollutant loading in the methodology should be well documented, substantiated, and approved by review agencies.

F.3.5 Storm Water Treatment

Comment #1
The report references the Caltrans report: CTSW-RT-02-044, *Tahoe Highway Runoff Characterization and Sand Trap Effectiveness Studies 2001-2002 Monitoring Session*; however, other pertinent Department reports do not appear to have been reviewed; in particular: CTSW-RT-01-050, *BMP Retrofit Pilot Program – Final Report*, January 2004, which provides extensive information on BMP design and performance;

(See: http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/index.htm)

The data development in the BMP Retrofit Pilot study is potentially a much better source for developing performance data than the facilities in the International BMP Database, because:

- The design characteristics of the Department sites are known and consistent, whereas the Database facilities consist of a wide variety of designs for each facility type – many of them unknown.
- The median effluent concentrations in the database are not the product of consistent design standards.
- All of the pilot sites are located in California.
- The Pilot Study final report provides equations that can be used to estimate effluent concentrations for a variety of influent concentrations, thereby accounting for differences in runoff quality from different land uses.

Response: The project team has reviewed the BMP Retrofit Pilot Program – Final Report described above and has referenced this document in the final report. The project team strongly agrees with the first two bullets above regarding the benefits of consistent design standards when monitoring and predicting effluent concentrations in BMPs. However, the project team disagrees that this particular study is a better source of performance data for Lake Tahoe relative to the International BMP Database. The International database includes over 50 BMPs studied by Caltrans. Additionally, the database includes monitoring data for an extensive range of climates, including climates similar to Lake Tahoe. Therefore, the project team feels that median concentrations contained in the International BMP database are the most robust source of data to use currently for the Tahoe Basin. As additional Tahoe Basin data is critically evaluated and collected, adjustments in the default values are recommended to reflect Tahoe conditions. See section 7.3.3 of the report for further discussion.

Comment #2

There should be reservation regarding confidence in the data given the use of a national dataset. For example in other areas of the country grass lined swales may be extremely well vegetated, whereas Tahoe, being high desert – vegetation is sparse, therefore less treatment. This may provide a bias high load reduction – giving a false estimated load at the end of the watershed.

Response: It is recognized that the performance data contained in the BMP database may differ from BMPs in the Tahoe Basin (Strecker et al. 2005). Confidence in the results can be gained by testing and comparison with Tahoe Basin data. However, Tahoe-specific data are currently too limited to develop statistically robust performance estimates for many BMP types. See Section 7.3.3. of the report for further discussion.

Comment #3

Figure 7.3 - Wouldn't the area of detention basins vary with depth of water? Is it not recommended that the user specify these variations?

Response: The stage-discharge characteristic provides the option to either use the default stage-area-discharge curve or provide a user-supplied curve. If a user-supplied *stage-discharge characteristic is selected the user must provide the depth, area, and discharge relationship in the space provided. When the default stage-discharge characteristic is selected the geometry of the detention facility is assumed to be a cylinder. This has been clarified in the final report.*

<u>Comment #4</u>
Constant infiltrative loss rate over 30 years of simulation will lead to significant over estimates of treatment efficiencies from BMPs. Consider discussing the implications of this in the body of the report instead of just in the final limitations section.

Response: Agree with limitation of current approach, but overestimates can be avoided by selecting appropriate long-term infiltration rates, or by simulating several sequential periods with declining rates. The current structure of report focuses on limitations in Section 8.

<u>Comment #5</u>
Don't the cold temperatures common to Tahoe have an effect on particle settling rates? The implications of this should be mentioned.

Response: Yes, but this is not a significant limitation of the current particle settling calculations. Discrete particle settling in the methodology is based on a simplified Dietrich formula and parameters used to calculate particle setting can be adjusted in the PLRE-STS (e.g., kinematic viscosity, specific gravity, etc.)

<u>Comment #6</u>
The report describes media filters as flow-based BMP's. This is true only for StormFilter and equivalent. All other media filters are volume based. This, unfortunately, is a repetition of erroneous information contained in the SASQA handbooks.

Response: Any storm water treatment BMP within the methodology and associated PLRE-STS can be simulated as either flow-based or volume-based by defining the categories of BMP design information provided.